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ORIGINAL ARTICLES.

I.—Notes on the Semi-Arid Conditions in a Part of Southern Texas.

By T. O. Bosworth, D.Sc., B.A., F.G.S.

(PLATES XVI AND XVII.)

Introduction.—The conditions described below were observed over a large part of South-West Texas; but the local details apply to an area of one or two hundred square miles in McMullen County, geologically surveyed by the writer in 1912. The centre of observations was a little mining ranch named Crowther, about 50 miles south of San Antonio and 80 miles from the Gulf of Mexico, near the inland limit of the Gulf coastal plain. The country for many miles around Crowther is practically untouched by man, though a somewhat primitive little local railroad now under reconstruction reaches to within 16 miles of it.

Geological Structure of the Region.—The coastal plain is, say, about 100 miles wide, extending along the coasts of Louisiana, Texas, and Mexico. The strata are very slightly inclined towards the sea and strike approximately parallel with the coast. Apparently there has been a gradual recession of the sea, accompanied by a slight uptilting of the land, so that the Quaternary and latest Tertiary were not deposited far inland. Near the coast the plain is nearly flat and almost at sea-level. Inland the ground rises, imperceptibly at first, and then by successive gentle steps. Towards the inland limits of the plain there has been considerable denudation, and the rocks are well exposed. Continuing through this more rocky country, at length we reach the block-faulted Cretaceous beds beyond the plain. In the area considered, the United States Government has not yet carried out either its geological or topographical survey, but bulletins and maps have been published dealing with one or two other portions of the plain.[1]

Climatic Conditions.—From east to west along the coastal plain, there is a gradual change in climate, the Louisiana and South-East Texas end being moist, whilst the South-West Texas end is dry. The rainfall in McMullen County is about 22 inches, and most of it falls

[1] C. W. Hayes & W. Kennedy, "Oil Fields of Texas–Louisiana Gulf Coastal Plain": Bulletin B 212, United States Geological Survey.

quickly within a few weeks of the spring. The mean temperature exceeds 80° F. throughout the three summer months, but it is not much above 50° F. in January. The air is very clear, and mirages are visible in summer and autumn. The wind blows almost constantly in from the Gulf, and often is very strong, causing sand-storms. At times there is a sudden fall in temperature brought about by a cold wind from the North, known as a 'Norther', which occasionally attains to the violence of a mild hurricane.

Geology and Topography around Crowther.—Around Crowther the high ground (about 700 feet above sea-level) is a steep dissected escarpment or plateau, with bluffs sometimes nearly 100 feet high and outliers in the form of table-like hills. The high ground is capped by a series of nearly horizontal calcareous sandstones, shales, and clays, about 50 feet thick, containing marine fossils. Below is a thick series of soft sands and clays containing much fossil wood and a few freshwater shells. The lower ground viewed from afar off appears flat, but is found to be an irregular succession of different levels with small steep steps between them. The whole is intersected by innumerable steep narrow gullies. A few miles away to the south lies the wide River Frio, an intermittent stream whose waters join the River Nueces, which flows into the Gulf.

Fauna.—A few years ago wild cattle and horses roamed these plains, probably obtaining a bare living during the spring months and retreating elsewhere in the drier seasons. Amongst the present fauna are some deer, the coyote, hares and rabbits, rattlesnakes, the 'horned toad', birds, etc. Until quite recently a tribe of wandering Indians held sway, and their old camping-grounds are marked by numerous stone arrow-heads and other remains. There is a wide territory hardly touched as yet by man, except at a few places where Artesian water has been won to irrigate the land.

Vegetation.—The country is devoid of grass, but is more or less liberally sprinkled over with the prickly-pear cactus and stunted bushes of 'mezquit' and chaparal. All these plants are well protected with thorns and spines to resist any wretched animals which strive for existence on this barren land. In winter, cattle overcome with hunger and thirst will eat the prickly but juicy cactus leaves until their tongues are so bristling with long thorns that they are unable to draw them back into their mouths. Men who have kept cattle in these places go around the cactus bushes with gasoline lamps, burning off the thorns. The mezquit, besides being armed with thorns, has an exceedingly bitter taste, but the beans which grow upon this bush are the most serviceable fodder which the land provides. Notably amongst the other peculiar prickly desert plants is the large aloe, known as the 'Spanish dagger'. At the centre of this plant reaching often to a height of 10 or 12 feet is a straight flower-stem bearing a spire of thickly clustered flowers which the animals find edible. The flower is amply defended by a chevrise of long strong leaves of sword-like shape, with sharp points (see Pl. XVI, Fig. 1). Along some of the watercourses, however, are a few live oaks and other trees. Large trees grow profusely on the alluvial soil alongside the River Frio.

Denudation and Transportation.—Despite the scantiness of rainfall this is a region of conspicuously rapid denudation; and the transportation of the detritus to the sea is ever visibly in operation.

The Sun's Heat.—The sun's rays and changes of temperature, as usual in deserts, are causing cracking and crumbling on all bare surfaces, so that debris is continually falling down the sides of every scarp and gully. A curious instance was observed where the sun's heat had had a hardening effect. Here in the freshwater series are certain white clays (comparable with fire-clays) which are very dry and porous, and which can readily absorb much water and become plastic. In places the occasional rain has washed them, leaving smooth hummocks, and the heat of the sun has then baked these almost as hard as pot, so that they ring when struck with the hammer.

The Wind.—The wind is usually blowing steadily from the Gulf, and there is a constant visible drifting of material to northward into the valleys of the River Frio and its branches. So effective is the wind that in most cases the talus is disintegrated and removed from the foot of the hills as fast as it can form, and consequently the bluffs are but little protected, and steep scarps are the rule.

Pebbles.—The fragments of sandstone, calcareous sandstone, and claystone seldom survive even as small pebbles at any distance away from the cliffs, but are quickly reduced to their component grains. Nevertheless, the desert surface generally is littered over liberally with certain small pebbles which decrease in size at a distance from the bluffs, until in the flat plains they are about the size of beans. In places they are some inches apart, in others they almost conceal the sand (Pl. XVI, Fig. 2). These pebbles in this district are a peculiar assortment, for they consist almost all of chert, agate, chalcedony, and opal. The pebbles are cut so as to have many facets and many sharp edges and corners, and are highly irregular in shape: indeed, they resemble broken flints. None were found of the typical dreikanter pattern, though all are most highly polished and almost lustrous (Pl. XVI, Fig. 3). Approaching the bluffs they are larger and have less facets, and some can be found whose undersides are fractured surfaces which have not yet been presented to the wind. The source of this chalcedonic material is the marine series which caps the bluffs. In those rocks there are numerous fossils, most of which (corals, gasteropods, etc.) are preserved beautifully in semi-opalescent silica, many cracks in the rocks also being occupied by this material. The wide-spread pebbles probably indicate the former extension of the series over many miles, and are evidence of the considerable denudation effected under present conditions. Frequent also among the pebbles are larger stones consisting of silicified wood derived from the freshwater series. Some of the grey calcareous sandstones which form pebbles at the foot of the cliffs are somewhat curiously affected. Outside they have a white shell-like coating up to $\frac{1}{4}$in. thick (which is soluble in hydrochloric acid), and underneath this is a reddish coating of iron oxide. These materials presumably have been drawn out to the

surface of the stone by capillary action when heated by the sun after moisture has sunk into them.

The Sand and Soil.—The desert sand is derived from the rocks at hand; it is rather fine and not particularly rounded. It may be a few feet deep, but more often it is only a few inches, and even in the low flat ground bare rocks are here and there exposed. Occasionally sand completely covers a layer of pebbles, but generally it seems to be the presence of pebbles which enables the sand to remain at rest; vegetation may then obtain a footing and allow the accumulation of further sand. Where vegetation retains a hold, patches of rich dark soil are readily formed which is sometimes 3 or 4 feet thick. But owing to the wind (and also to the water-flows) the distribution of sand and soil is ever undergoing rapid change. At the ranch mentioned, for instance, an attempt was being made to grow a plot of maize; at one end of the plot a man was ploughing, but at the other end the ground ploughed the day before was so completely covered by sand that no marks of the plough were visible. Again, during the rains, the bare rocks became exposed in places where two days before there had been 3 feet of soil.

Work of Water.—The land surface is intersected by innumerable watercourses (Pl. XVII, Fig. 4) which lead ultimately northward and westward into the River Frio or its tributary, the San Miguel River. During the greater part of the year those rivers are dry, though a little water can usually be obtained by digging in the river-bed. At other times there is a moderate flow of water wandering about in a wide valley which is choked up with a great amount of sand and stones, often disposed in big shoals. These rivers are always overloaded, and at the time of the rains they become torrents bearing an immense load to the sea. The gullies leading into them are narrow gorges up to, say, 30 feet deep, with steep sides, often vertical. By their complicated windings and the windings of their countless little tributaries where they converge they dissect the ground into 'bad lands' on a small scale (Pl. XVII, Fig. 5). Further from the river the creeks become much smaller, so that the area is mainly cut up by a network of narrow little dry gullies a few feet deep. It was the writer's good fortune to be present in April when the rains came. The creeks filled immediately, and overflowed so that sheets of water spread far and wide, flowing out over the sand and forming large 'water spreads'. Fresh watercourses were cut from day to day, so that the system was completely changed. Talus was washed away from the bluffs, pebbles were spread out or washed up into banks, new shoals of sand were formed, stunted trees were uprooted, and soil removed. At intervals between the rain-storms, which usually occurred at night, the sun shone brightly, the waters partly dried up and revealed in the creeks and on the flats fresh sand and mud surfaces all marked with water-ripples and sun-cracks, where previously had been wind-ripples or dry sand.

Ripples.—These water-ripples, whether in the creeks or on the flat, when formed by advancing water present one constant pattern, generally in high relief—a kind of horseshoe pattern with all the 'shoes' leading forward (Pl. XVII, Fig. 6). At bends in the

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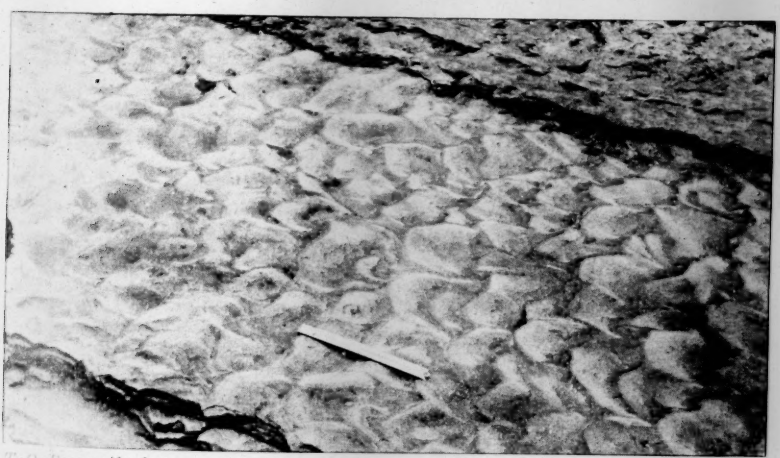

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T. O. Bosworth photo.

Arid Surface-features in South-West Texas.

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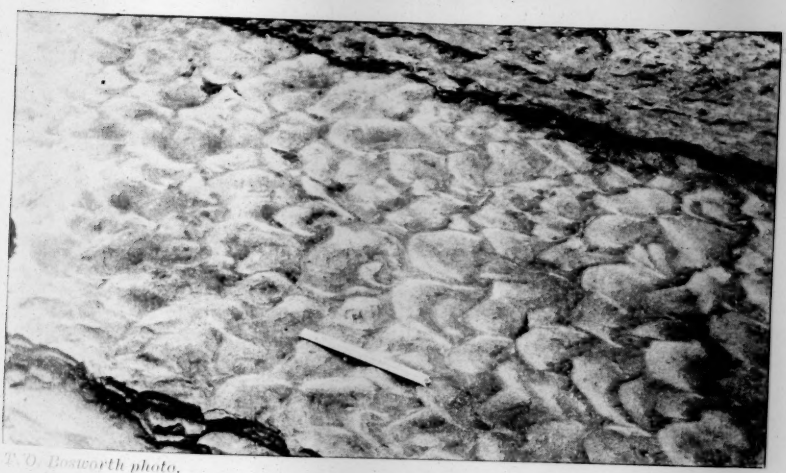

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T. O. Bosworth photo.

Arid Surface-features in South-West Texas.

course of the current the 'horseshoes' are obliquely distorted.[1] The wetted surfaces, having the appearance of mud flats, are rapidly cracked up by the sun's heat into hexagonal patterns with wide cracks. Drying proceeds rapidly and sometimes surface films of the hexagons may be seen curling up, each into a thin roll, and then crumbling up into ordinary fine quartz sand. Remarkably rapid was the effect of the sudden rains upon the vegetation. The stunted mezquit bushes put forth abundant light yellow-green leaves, and in a day or two the ground was ablaze with bright-coloured flowers, so that in every direction as far as the eye could see the earth appeared red or blue or yellow, or of varied hue, as the case might be. (These small plants display much flower and very little leaf.) A multitude of small Gasteropods feed upon this vegetation.

Gypsum.—Gypsum is being formed almost everywhere. In the floors of the gullies are occasional growths, several feet across, composed of spherulitic structures, the spherules being upwards of several inches in diameter and built of radiating fibres. On all talus slopes where there is argillaceous material, thin sheets and slabs of gypsum are ever forming. They appear to grow a few inches beneath the surface, and also in cracks. The slabs are formed of fibres normal to the plane, and are usually only a fraction of an inch in thickness, though some are thicker. There are also single larger crystals of selenite of the usual form. It appears that gypsum grows very readily in argillaceous matter which is much exposed to the sun's heat and is occasionally moistened.

Desert Deposits.—Although the whole region is overspread with sand, yet nowhere were any thick deposits observed to be forming. Indeed, the resultant effect of wind and water in this area is gradual denudation, with intermittent sudden transferences of material to the River Frio, and thence by sudden impulses to the sea. The deposit due to the denudation in this desert is a delta cone in the Gulf of Mexico, and it is only there that the blown sand and the multitude of hard wind-cut stones come to a lasting rest.

EXPLANATION OF PLATES XVI AND XVII.

FIGS.

PLATE XVI.

1. Characteristic vegetation of the arid regions of Texas, consisting of: 'prickly-pear cactus' (*Opuntia vulgaris*), 'Spanish dagger,' the large aloe (*Yucca aloifolia*), bushes of 'mezquit' (*Prosopis glandulosa*), and 'chaparal' (thick bramble-bushes entangled with thorny shrubs in clumps).
2. Sand and stone-covered plains (typical view).
3. Wind-cut pebbles on the desert (mainly chalcedony).

PLATE XVII.

4. A dry watercourse.
5. Tributary entering the River Frio valley (the foreground is one bank of the tributary). In the background is the Frio valley.
6. After the rains. The surface shows the form of the ripples left by a water-flow; all of horseshoe pattern, with the 'footmarks' pointing forward.

[1] Rarely (as in some places where steady flows lapped a sandbank) a more linear type of ripple was seen on sloping surfaces. Also linear forked ripples were formed occasionally in still pools where the water was agitated by wind.

II.—The Twelfth International Geological Congress in Canada.

By B. Hobson, M.Sc., F.G.S.

At the Stockholm meeting of the Congress in 1910 an invitation to hold the twelfth meeting in Canada was accepted. As the Congress met in the United States in 1891 and in Mexico in 1906, members were thus afforded an opportunity of visiting all the great divisions of North America. The Canadian meeting was held at Toronto from August 7 to 14, 1913, under the presidency of Professor F. D. Adams, of McGill University. About 600 members attended it, although the total enrolled was nearly twice as great, and 46 countries were represented among the members. The Congress was formally opened by the Right Hon. Sir Charles Fitzpatrick, on behalf of H.R.H. the Duke of Connaught, the Honorary President, who was unavoidably absent, and speeches of welcome were made by others. Dr. R. W. Brock, Director of the Geological Survey of Canada and General Secretary of the Congress, presented to the Congress a monograph entitled "The Coal Resources of the World", the result of an inquiry made upon the initiative of the Executive Committee of the Twelfth Congress, with the assistance of Geological Surveys and mining geologists of different countries. It consists of three quarto volumes of about 400 pages each (11 by $8\frac{1}{4}$ inches) and an atlas of 66 pages of maps in colours ($13\frac{1}{2}$ by $19\frac{1}{2}$ inches) published by Morang & Co., of Toronto, at $25 per set, net. It forms a fitting companion to the volume on the Iron Ore Resources of the World, published under the auspices of the Stockholm Congress.

In the second circular of invitation to the Toronto Congress seven topics were mentioned as having been selected by the Executive Committee as the principal subjects of discussion. The first of these was "The Coal Resources of the World". Not much was said on this subject, no doubt owing to those best qualified to speak having given their views in the monograph. The second subject was "Differentiation in Igneous Magmas". On this subject Professor R. A. Daly read a paper entitled "Sills and Laccoliths illustrating Petrogenesis". He advocated gravitative differentiation and tabulated seventy different sills and laccoliths, in twenty-nine of which he maintained that such differentiation is shown. He also maintained that many species of igneous rocks are due to large-scale assimilation of country rocks by overhead or other stoping, giving rise to syntectic magmas. Dr. A. Harker followed with a paper on "Fractional Crystallization the Prime Factor in the Differentiation of Rock Magmas", in which he pointed out that a rock magma at a temperature below that of the upper part of the temperature range of crystallization must be pictured as an open fabric or sponge of crystalline matter with interstices occupied by liquid magma. Under crustal stresses the interstitial liquid may be squeezed out and thus differentiation may arise, as the crystalline and liquid parts necessarily differ in composition. A stratification and differentiation may also be brought about by gravity acting upon a wholly fluid magma or (more effectively) by the sinking of crystals in a magma still mainly fluid.

Dr. Iddings in a paper on "Some examples of Magmatic Differentiation and their bearing on the problem of Petrographical Provinces" agreed with Dr. H. S. Washington in emphasizing the importance of sufficient analyses. In Dr. Washington's paper on "The Volcanic Cycles in Sardinia" he pointed out that there are three cycles—firstly, that of the extensive early (Tertiary) flows; secondly, that of the two large volcanoes of Monte Arci and Monte Ferru; thirdly, that of the small recent scoria cones. In the first two cycles the sequence began with acid, followed by intermediate and basic rocks. The lavas of the third cycle are felspar basalt in which no definite sequence has as yet been made out. Rocks of typically Atlantic and others of typically Pacific type occur in Sardinia, even in the same volcano, as at Ferru and Arci. Professor W. H. Hobbs in a paper on "Variations in Composition of Pelitic Sediments in relation to Magmatic Differentiation" endeavoured to account for some of the variations in igneous rocks usually attributed to differentiation by supposing many igneous rocks to be the result of the fusion of argillaceous sediments. Dr. V. Sabatini gave "A Classification of the Eruptive Rocks of Italy". The discussion was continued by Dr. J. W. Evans, Professor F. Loewinson-Lessing, Professor A. Bergeat, Dr. W. Cross, and summed up by Professor H. Bäckström, who advocated reserving judgment until more experimental work has been done.

The third subject discussed was the "Influence of Depth on the Character of Metalliferous Deposits". Professor J. F. Kemp opened the discussion with a paper bearing that title. He concluded that (1) while there seems to be nothing to prevent precipitation at greater depths than we have yet reached, yet conditions seem to be specially favourable in those portions which lie between the present surface and 2,000–4,000 feet in depth; (2) secondary enrichment has increased the yield of those portions of many veins which are above 1,000 feet in depth, the vertical extent of its action being limited to a relatively short stretch below the ground-water level. Professor J. P. Krusch followed with a paper on the colloidal precipitation of primary and secondary ores. Professor W. H. Emmons in "The Mineral Composition of Primary Ore as a factor determining the Vertical Range of Metals deposited by Secondary Processes" outlined the processes of enrichment of sulphide ores of gold, silver, and copper, and reviewed some of the more important experiments that may illustrate this process. Dr. L. L. Fermor "On the Formation in Depth of Oxidized Ores and of Secondary Limestones" stated and illustrated the thesis that when deposits consisting of chemical sediments, such as oxides and carbonates as of iron, manganese, or calcium, admixed with mechanical sediments, such as sand and clay, are buried to a depth sufficient to bring them into the zone of anamorphism, reactions take place, which frequently necessitate the elimination from the oxides of oxygen in excess of protoxide proportions, as from Fe_2O_3 and MnO_2; of carbon dioxide from carbonates; and of water from hydrated oxides, such as limonite. It seems to be usually tacitly assumed that these escape or are removed from the scene of action, but it is conceivable that the pressure is such that they are unable to escape. When, in course

of time, this pressure is released these substances will probably effect a reversal of the original change. P. F. Fanning gave "A contribution to the Metallogeny of the Philippine Islands", and Dr. M. Maclaren a paper on "The Persistence of Ore in Depth".

The fourth topic discussed was "The Origin and Extent of the Pre-Cambrian Sedimentaries". Dr. J. J. Sederholm in "Different Types of Pre-Cambrian Unconformities" described the conditions in Fenno-Scandia, and incidentally mentioned that "it seems that our separation of the strongly metamorphic schists, near Lake Ladoga, from the Kalevian proper, as a much older subdivision, designated Ladogian, was founded on an erroneous correlation between the post-Kalevian granites at Lake Ladoga and the younger pre-Kalevian granites of Western Finland". In a second paper "On Regional Granitization (or Anatexis)" Sederholm described palingenesis or the formation of new rocks in Finland by the refusion *in situ* of pre-existing igneous or sedimentary rocks. Professor G. A. J. Cole gave "Illustrations of the Formation of Composite Gneisses and Amphibolites in North-West Ireland". Professor W. S. Bayley described "The Pre-Cambrian Sedimentary Rocks in the Highlands of New Jersey". Dr. G. F. Matthew dealt with "Cambrian and Pre-Cambrian in the Maritime Provinces of Canada".

The fifth subject discussed was "The Subdivisions, Correlation, and Terminology of the Pre-Cambrian". Dr. A. Strahan gave an account of "The Subdivisions and Correlation of the Pre-Cambrian Rocks of the British Isles", and stated that we seem to lack justification for attempting a chronological sequence of pre-Cambrian rocks in the British Isles, further than is involved in placing the Lewisian gneiss among the oldest, and the Torridonian among the later formations. Dr. J. Horne described the pre-Cambrian and Dalradian rocks of Scotland. Professor A. C. Lawson read a paper on "A Standard Scale for the Pre-Cambrian Rocks of North America", in which he took the Lake Superior region as typical, and tabulated in ascending order Coutchiching, Kewatin (grouped together as Ontarian), Laurentian granite gneiss, batholithic in Ontarian, *Unconformity*, Lower Huronian, *Unconformity*, Upper Huronian, Algoman granite gneiss, batholithic in Huronian, *Eparchæan Interval*, Animikie, *Unconformity*, Keweenawan (Nipigon), grouped together as Algonkian, *Unconformity*, Upper Cambrian (Potsdam). Mr. W. H. Collins, of the Geological Survey of Canada, in "A Classification of the Pre-Cambrian Formations in the region east of Lake Superior", announced that the gap of 70 miles between the Sudbury and the Cobalt districts has been investigated by the Geological Survey and was closed last autumn so that the sequences in the two areas can be correlated, and he gave a table of correlation. Professor A. P. Coleman read a paper on "The Sudbury Series and its bearing on Pre-Cambrian Classification". The impression made upon the writer by the discussion on American pre-Cambrian classification was that hardly two authorities agree, and that the grouping under the name of Huronian of three or more systems, separated by great unconformities, only leads to confusion. Mr. E. Vredenburg and Sir T. H.

Holland gave separate papers on the classification of the pre-Cambrian in India, and Dr. J. J. Sederholm read "Some Proposals concerning the Nomenclature of the Pre-Cambrian, etc.", the most important of which led to a resolution passed by the Congress that countries which possess contiguous areas of pre-Cambrian rocks should form international committees, including representatives of their Geological Surveys, for the purpose of correlating their pre-Cambrian formations.

The sixth topic of discussion was "To what extent was the Ice Age broken by Interglacial Periods?" Mr. G. W. Lamplugh opened the discussion with a paper on "The Interglacial Problem in the British Isles". [This subject was dealt with in detail in his address to the Geological Section of the British Association at York in 1906.] He now stated that his views "have not been modified since in any essential particular", nor could he see any "reason for supposing that our Islands had been more than once enwrapped by ice-sheets, however the case may stand in other countries"; and is of opinion "that the great ice-sheets held their ground in the basins surrounding our Islands throughout the deposition of the drift series, and that the supposed Interglacial deposits are indicative only of marginal fluctuations and of the independent culmination of separate lobes during the long period of glaciation".

Professor A. P. Coleman gave "An Estimate of Post-Glacial and Interglacial Time in North America"; Mr. N. O. Holst gave (in French) "The Beginning and End of the Glacial Period"; Dr. Warren Upham, "The Sangamon Interglacial Stage in Minnesota and Westward." Professor T. F. W. Wolff, "On Glacial and Interglacial in North Germany," stated that there were three glaciations in that region, and that at Phöben near Potsdam in one and the same bore-hole two stratigraphically and faunistically distinct interglacial horizons occur, the lower with *Paludina diluviana* and the upper with *P. Duboisii*.

The seventh topic for discussion was "The Physical and Faunal Characteristics of the Palæozoic Seas, with reference to the value of the Recurrence of Seas in establishing Geological Systems". Professor T. C. Chamberlin contributed "The Shelf Seas of the Palæozoic and their relations to Diastrophism and Geological Systems". Professor G. Steinmann followed with "The Palæozoic Seas in South America". Professor C. Schuchert read a paper on "The Delimitation of the Geologic Periods illustrated by the Palæogeography of North America". He has drawn up eighty-five maps of North American geographies since the Cambric. He proposes to divide geologic time into periods based on the amount of submergence as measured by the area submerged as shown on these maps. The Cambrian is divided into Waucobic, Acadic, Ozarkic; the Ordovician into Canadic, Ordovicic, Cincinnatic; the Mississippian into Mississippic, Tenneseic; while the Pennsylvanic and Permic are united in a single system. Dr. E. O. Ulrich discussed "The Ordovician–Silurian Boundary", and incidentally rejected Schuchert's Cincinnatic System. Professor F. Frech described "The Palæozoics of the Bagdad Railway". Dr. O. Holtedahl in his paper "On the Old Red

Sandstone Series of North-Western Spitzbergen" gave the following correlation :—

Spitzbergen.	*Thickness.*	*Scotland.*
Wijde Bay Series	2,000 metres	Upper Old Red.
Grey Hoek Series	2,000 ,,	Middle Old Red (Orcadian).
Wood Bay Series	2,500 ,,	Lower Old Red (Caledonian).
Red Bay Series	2,300 ,,	Downtonian.

For want of guide fossils in the Grey Hoek Series its contemporaneity with the Middle Old Red is not proved. A paper on Periodicity of Palæozoic orogenic movements by T. C. Chamberlin and R. T. Chamberlin was also read. Six papers on tectonics and many miscellaneous papers were contributed, among which two papers on the geology of Argentina, by H. Keidel and Bailey Willis respectively, deserve special mention.

No account of the meeting of the Geological Congress in Canada would be complete without a reference to the excursions, which were to many the most attractive feature. Twelve excursions were arranged to take place before the meeting. The chief of these were that to Quebec and the Maritime Provinces, led by G. A. Young, J. M. Clarke, E. R. Faribault, etc., occupying nineteen days; that to Haliburton–Bancroft (Ontario), conducted by F. D. Adams and A. E. Barlow, seven days; and that to Sudbury–Cobalt–Porcupine (Ontario), led by W. G. Miller, ten days. Ten short excursions took place during the meeting and nine excursions after the meeting. The chief of these were the two great transcontinental excursions, C 1, by the Canadian Pacific main line over the Kicking Horse Pass to Victoria, Vancouver Island, and back, twenty-three days, and C 2, by the Crow's Nest Pass to the same place and back, twenty-three days, and last, but not least, C 8, to Yukon and Malaspina and back, twenty-five days. The excursions were splendidly organized, and in connexion with them guidebooks, in ten sections, divided into thirteen handbooks, were prepared. These comprised a total of 2,012 pages, illustrated by 154 maps, mostly coloured, 41 sections or drawings, and 281 process reproductions of photographs. They not only summarize pre-existing knowledge, but contain much new material.

If in this short account little has been said of the public functions, such as the conferring of honorary degrees and the unveiling at Percé and at Ottawa of memorial tablets to Sir William Logan, strict limitations of space must be the writer's excuse.

III.—On the Important Part played by Calcareous Algæ at certain Geological Horizons, with Special Reference to the Palæozoic Rocks.

By Professor E. J. Garwood, M.A., V.P.G.S.[1]

(*Continued from the October Number, p. 446.*)

IT is now time to turn to the consideration of the part played by these organisms in the formation of sedimentary rocks through the successive geological periods.

[1] Edited and slightly abridged with the author's permission from the original Address as delivered at Birmingham, before Section C at the British Association meeting.

Archæan.

In the Archæan rocks no undoubted remains of Calcareous Algæ have yet, so far as I am aware, been recorded, but Sederholm considers that certain small nodules in the Archæan schists of Finland may represent vegetable remains. I may also perhaps here refer to some curious oolitic structures which I met with in Spitzbergen in 1896 when examining the rocks of Hornsund Bay. These oolites occur on the south side of the bay, and are closely connected with massive siliceous rocks which may represent old quartzites. The whole series is much altered, and detailed structure cannot now be made out. The rocks occur apparently stratigraphically below the massif of the Hornsund Tinde, and may belong either to the Archæan or the base of the Heckla Hook Series. As, however, similar rocks have not been recorded from the type district of Heckla Hook, they may be referred provisionally to the Algonkian, and may represent the quartzites and earthy limestone of the Jotnian Series of Scandinavia. They are mentioned here in connexion with Mr. Wethered's view that oolites are essentially associated with the growth of *Girvanella*.

Cambrian.

Passing on to the Palæozoic rocks, we find in the Cambrian deposits but few indications that Calcareous Algæ played any considerable part in their formation.

This is no doubt due, to some extent, to the conditions under which these deposits accumulated in the classical localities where true calcareous deposits are typically absent. In the Durness Limestone, however, where considerable masses of dolomites occur, the conditions would appear at first sight to have been more suitable for the growth of these organisms; but even here the slow rate of accumulation and the large amount of contemporaneous solution may have militated against their preservation. At the same time, it is possible that a systematic search in the calcareous facies of the Cambrian rocks in the North of Europe and America may result in the discovery of the remains of some members of this group. That there is ground for this suggestion is shown by recent work in the Antarctic Continent.

Professor Edgeworth David and Mr. R. E. Priestley have discovered among the rocks on the north-west side of the Beardmore Glacier dark-grey and pinkish-grey limestone containing the remains of Archæocyathinæ, Trilobites, and sponge spicules, together with abundant remains of a small calcareous alga referred provisionally to *Solenopora*. From the photographs exhibited by Professor David on the occasion of his lecture (February 8, 1911) to the Geological Society, I have little doubt that this reference is correct.

A further occurrence of *Solenopora* is also reported from fragments of a limestone breccia collected by the Southern party from the western lateral moraine of the same glacier. Speaking of the fauna discovered in this limestone Professor David remarks: "The whole assemblage is so closely analogous with that found in the Lower Cambrian of South Australia as to leave no doubt as to the geological age of the limestones from which these fragments are derived."[1] This discovery,

[1] Eleventh Internat. Geol. Congress Report, 1910, p. 775.

therefore, extends the vertical range of this widely distributed genus down to the oldest Palæozoic rocks. It is interesting to note that the rocks in which the *Solenopora* occurs on the Antarctic Continent contain a development of pisolite and oolite, and that this is also the case in the Australian equivalents. In 1887 and again in 1891 Bornemann described and figured species of *Siphonema* and *Confervites*[1] from the *Archæocyathus* limestones of Sardinia. As regards the former genus, it was shown by Dr Hinde[2] to be congeneric with *Girvanella* (Nich. & Eth.). It is of interest, however, to note that Bornemann describes this form as a calcareous alga, and compares it with existing subaerial Algæ growing on the surface of limestone rocks in Switzerland. The latter genus is stated by Seward to be possibly "a Cambrian alga, but the figures and descriptions do not afford by any means convincing evidence" (*Fossil Plants*, vol. i, p. 178).

More recently, in 1904, Dr. T. Lorenz[3] has described remains of *Siphoneæ* from the Cambrian rocks of Tschang-duang in Northern China, for which he erects two new genera, *Ascosoma* and *Mitscherlichia*, placing them in a new family, the Ascosomaceæ. These Algæ build important beds of limestone, the individuals often attaining a length of 4 cm. and a thickness of 1·5 cm. In 1907 Bailey Willis[4] reported *Girvanella* associated with oolites in the lowest Cambrian Man-t'o Beds in China. It is probable, therefore, that as our knowledge of these rocks is extended, Calcareous Algæ will be found to play an important part in the Cambrian limestones of the Asiatic Continent and Australia.[5]

Ordovician.

In the Ordovician rocks the remains of Calcareous Algæ become much more abundant; they are very widely distributed and for the first time they become important rock-builders. In Britain the chief genera met with are *Girvanella* and *Solenopora*. These two organisms occur abundantly in the Scottish Ordovician rocks of the Girvan area, where they appear to have contributed largely to the limestones of the Barr Series in Llandeilo–Caradoc times.

As already mentioned, *Girvanella problematica* was originally described by the late Professor Nicholson and Mr. R. Etheridge, jun., from the Craighead Limestone at Tramitchell, where it occurs in great numbers. The officers of the Geological Survey also report it from the Stinchar Limestone of Benan Hill.[6] It occurs in the form of small rounded or irregular nodules, varying in diameter from less than a millimetre to more than a centimetre, many of the nodules showing marked concentric structure. In Benan Burn, where these beds are admirably exposed, the *Girvanella* nodules appear conspicuously on the weathered surfaces, being so abundant as to constitute thick layers of limestone.

[1] Nova Acta Cæs. Leop. Car., 1887 and 1891.
[2] Hinde, Geol. Mag., Dec. III, Vol. IV, p. 226, 1887.
[3] Centralb. f. Min., 1904, p. 193.
[4] *Research in China*, 1907.
[5] Chapman, Proc. Roy. Soc. Vict., 1911, p. 308.
[6] *The Silurian Rocks of Britain*, vol. i, Scotland (Mem. Geol. Surv. U.K.), pp. 487, 494, 496, 500.

Solenopora compacta, var. *Peachii*, which likewise forms important masses of limestone, is found, like *Girvanella problematica*, most abundantly in the Girvan area, but at a somewhat lower horizon, namely, in the 'nodular limestone' and shales forming the lower subdivision of the Stinchar Limestone. The horizon of the Stinchar Limestone is correlated by Professor Lapworth with the Craighead Limestone, and considered to represent the summit of the Llandeilo or the base of the Caradoc rocks of the Shropshire district. It is of interest to note that *Solenopora* is here accompanied at times by well-marked oolitic structure, and that the same is true of the pebbles with which it is associated in the conglomerate at Habbie's Howe.

Although the marked development of *Solenopora* found in the Stinchar Limestone ceases with the advent of the Benan conglomerate, the genus appears to have survived in the Girvan district into Upper Caradoc times, for Dr. Brown describes a new species (*S. lithothamnioides*) from Nicholson's collection from the Ordovician (? Silurian) beds at Shalloch Mill, where it is said to occur in conical masses the size of a walnut. Specimens of *Solenopora* from Shalloch Mill in Mrs. Gray's collection were obtained from Professor Lapworth's Whitehouse Group.

South of the Scottish border there is, so far as I am aware, only one locality from which Calcareous Algæ have been recorded in rocks of Ordovician age, namely, Hoar Edge in Shropshire. Here large examples of *Solenopora compacta* were obtained in 1888 by Professor Lapworth from the calcareous layers near the base of the Hoar Edge Sandstone. The specimens were handed to Professor Nicholson, who records the circumstance in his description of *S. compacta* in 1888.[1] The form occurs here at the base of the Caradoc beds, and therefore at an horizon which corresponds closely to that of the Craighead Limestone of Girvan.

Professor Lapworth also informs me that he has obtained specimens of *Solenopora* from a limestone in south-west Radnorshire. As the upper portion of the limestone in which it is found contains a Silurian fauna, it is possible that it is here present at a higher horizon, though the constancy with which it occurs elsewhere, in beds of Llandeilo–Caradoc age, would seem to point to the possibility that beds of Upper Ordovician age are also present in this area. In any case its occurrence here is of considerable interest.

Foreign Ordovician.

Outside of Britain the most important development of Calcareous Algæ in rocks of Ordovician age is found in the Baltic Provinces.

Solenopora occurs here in the Upper Caradoc or Borckholm Beds of Schmidt's classification—where it makes up thick beds of limestone—and it is noteworthy that this horizon is practically identical with that at which *S. lithothamnioides* (Brown) occurs at Shalloch Mill.

Other specimens of *Solenopora* were collected by Professor Nicholson in Saak, south of Reval, from the underlying Jewe Beds, an horizon which must correspond very closely to that of the Craighead Limestone

[1] GEOL. MAG., Dec. III, Vol. V, p. 22, 1888.

of Girvan. Speaking of these beds Nicholson & Etheridge remark: "At this locality *S. compacta* not only occurs as detached specimens of all sizes, but it also makes up almost entire beds of limestone; indeed, some of the bands of limestone at Saak look like amygdaloidal lavas, while others have a cellular appearance from the dissolution out of them of the little pea-like skeletons of this fossil." [1]

In Professor Nicholson's collection from these beds Dr. Brown [2] afterwards distinguished two new species, namely, *S. nigra* and *S. dendriformis*. Thus, in the Ordovician rocks of Esthonia, *Solenopora* plays quite as important a part (as a rock-forming organism) as it does in the Girvan district in Ayrshire.

In Norway, again, in the Mjösen district to the north of Christiania, *Solenopora* occurs plentifully in Stage 5 of Kiær's [3] Ordovician series. Here it is very abundant and often builds entire beds, while, further east, at Furnberg, Kiær again records the occurrence of abundant nodules of *Solenopora compacta*, var. *Peachii*.

In addition to *Solenopora*, however, examples of another important group of Calcareous Algæ, the Siphoneæ, occur in great abundance in the Ordovician rocks of the Baltic region, where they play a part in the formation of calcareous rocks scarcely less important than that played by *Gyroporella* and *Diplopora* in the rocks of the Alpine Trias.

The chief forms belong to the family of the Dasycladaceæ, which is represented in our present seas by the recent genus *Neomeris*; they include the genera *Palæoporella*, *Dasyporella*, *Rhabdoporella*, *Vermiporella*, *Cyclocrinus*, and *Apidium*. These algal limestones represent the horizons from the Jewe Limestone to the Borckholm Beds inclusive. They were originally investigated by Dr. E. Stolley,[4] who described their occurrence in the numerous boulders which are strewn over the North German plain in Schleswig-Holstein, Pomerania, Mecklenburg, and Mark-Brandenberg. The facts appear to show that during the deposition of the Jewe and the overlying Wesenberg and Lyckholm Limestones an algal facies obtained which extended from Oeland to Estland, and as far north as the Gulf of Bothnia. But even this area does not represent the full extent of the algal limestone facies in the North of Europe in Upper Ordovician times. In Norway, Kiær [5] has shown by his detailed work in the Upper Ordovician rocks (Stage 5) of the Christiania district, the important part played by the Dasycladaceæ in this area. Here the Gastropod limestone in places forms a 'phytozoan limestone', made up of *Rhabdoporella*, *Vermiporella*, and *Apidium*, associated with a considerable development of oolite.

Again, at Kuven and Valle, in the Bergen district, Reusch [6] and

[1] Geol. Mag., Dec. III, Vol. II, p. 534, 1885.
[2] Geol. Mag., Dec. IV, Vol. I, p. 145 et seqq., 1894.
[3] "Faunistische Uebersicht d. Et. 5": Vid. Selsk. Skr., 1897, No. 3.
[4] Schr. d. naturw. ver. f. Schleswig-Holstein, Bd. xi, 1897, and references there given.
[5] Etage 5 i. Asker. Norges Geol. undersogeles Aarbog, 1902, No. 1.
[6] *Silurfossiler og pressede Konglomerate*, 1882. "*Bømmelø en og Karmø en*": Med. omgiveleser, 1888.

Kolderup[1] have described knolls of crystalline limestone containing abundant remains of *Rhabdoporella* (formerly described as *Syringophyllum*) associated with a Gastropod and coral fauna.

We have, therefore, in Upper Ordovician times, in the North of Europe, one of the most remarkable developments of algal limestones met with throughout the geological succession. In North America Calcareous Algæ are represented in Ordovician times by *Solenopora compacta*, which occurs in the Trenton and Black River Limestone groups, whence it was originally described by Billings under the name *Stromatopora compacta*. It therefore occurs in America at about the same horizon as in Saak and Britain.

We may also note the occurrence of *Girvanella* in the underlying Chazy Limestone. This occurrence was originally described by the late Professor H. G. Seeley[2] under the name of *Strephochetus ocellatus*, but is now generally admitted to be a species of *Girvanella*.[3]

Other forms referred to this genus have also been reported by Schuchert from rocks of undoubted Ordovician age on the east coast of the Behring Straits.[4]

Silurian.

In Britain the only horizon of Silurian age at which Calcareous Algæ play an important part is the Wenlock Limestone. Some years ago Mr. Wethered described the occurrence of *Girvanella* tubes in the beds of this age, especially at May Hill, Purley, near Malvern, and near Ledbury.[5]

Foreign Silurian.

Outside of Britain, however, we find at this period a marked algal development, and this again occurs in the Baltic area, where, especially in the island of Gotland, algal growths contribute largely to several of the limestones and marls. It is an interesting fact that very shortly after the disappearance of the various members of the Dasycladaceæ which were so much in evidence in Ordovician times, we should have the remarkable development of another group of the Siphoneæ, which, quickly reaching a maximum, built up in their turn abundant calcareous deposits. Nodules from these limestones have long been known from Gotland under the name of 'Girvanella Rock', and have been recorded by Stolley[6] in boulders scattered over the North German plain. In 1908, however, Professor Rothpletz showed, in his interesting work on these Gotland deposits,[7] that the forms hitherto alluded to under the term '*Girvanella*' were in reality referable to two different genera. One of these he showed to be a new species of *Solenopora*, to which he gave the name *S. gotlandica* (distinguished from *S. compacta* by the comparatively small dimension of the tubes,

[1] *Et orienterende niveau Bergenskiffe, Rhabdoporellenkalk von Kuven und Valle*, Bergens Museums, Aarbog, 1897.

[2] Am. Journ. Sci., vol. xxx, p. 355, 1885.

[3] Geol. Mag., Dec. III, Vol. IV, p. 226, 1887.

[4] See Haug, vol. ii, pt. i, p. 643.

[5] Q.J.G.S., vol. xlix, p. 236, 1893.

[6] Schr. d. naturw. ver. f. Schleswig-Holstein, Bd. xi, 1897, and references there given.

[7] Kungl. Svenska Vet. Akad. Handl., Bd. xliii, No. v, 1908.

which are only about one-quarter of the diameter of the latter species); the other he referred to his genus *Spherocodium*, which he had created in 1890 for certain forms from the Alpine Trias.[1] The survival here of *Solenopora* into beds of undoubted Silurian age is an interesting fact, and would lead us to expect that it may also some day be met with in rocks of a corresponding age in Britain.

Of the different forms of Algæ which occur in these Gotlandian deposits, perhaps the most interesting is *Spherocodium*, which, as shown by Dr. Munthe,[2] occurs at several horizons in the succession. It first makes its appearance in the marl immediately overlying the Dayia Flags — approximately of Lower Ludlow age — where it occurs in considerable masses. In external appearance these resemble very closely nodules of *Ortonella* from the Lower Carboniferous rocks of the North-West of England; some of the nodules appear to have reached a diameter of 4 cm. The marl is overlain by sandstone and oolite, which are succeeded by an argillaceous limestone rich in nodules of *Spherocodium gotlandicum* and well exposed at Grötlingbo, where it is closely associated with oolite. Among the fossils of this limestone *Spherocodium* itself plays the most important rôle.

In the overlying 'Iliona Limestone' *Spherocodium* is decidedly rare, and its place is taken by *Spongiostroma*. As will be pointed out later, there appears to be no good reason why *Spongiostroma* may not be indirectly due to the presence of algal growths; but whatever may be the final position assigned to it, there can be no doubt as to its importance as a rock-building form in the Iliona Limestone of Gotland. We may conclude, therefore, that the development of the *Spherocodium* beds of Gotland probably occupied originally nearly as wide an extension in the Baltic area as did the *Rhabdoporella* limestones during the Ordovician Period.

With regard to other occurrences of Calcareous Algæ in Silurian rocks, it will be sufficient to note that of *Girvanella* in the Silurian limestones of Queensland, recorded by Mr. G. W. Card in 1900,[3] and more recently by Mr. Chapman from Victoria.[4]

Quite recently Mr. R. Etheridge, jun., of Sydney,[5] has described "an organism allied to *Mitcheldeania* from the Upper Silurian rocks of New South Wales"; the figures given, however, and the description are not convincing that his identification can be accepted. The size of the tubes, which are from five to six times as large as those of *M. gregaria*, would alone appear to remove this organism from Mr. Wethered's genus and also possibly from the Calcareous Algæ.

Devonian.

So far as I am aware, there is only one recorded occurrence of Calcareous Algæ from the Devonian rocks of Britain—namely, in the Hope's Nose Limestone of Devonshire, from which Mr. Wethered has described aggregations of tubules resembling *Girvanella*, but in a very poor state of preservation.

[1] Bot. Cent., vol. lii, p. 9, 1890.
[2] Geol. Foren. Forh. Stock., Bd. xxxii, Hft. v, p. 1397, 1910.
[3] Bull. Geol. Surv. Queensland, 1900, No. 12, pp. 25–32, pl. iii.
[4] Rep. Austr. Assoc. Adv. Sci., 1907–8, pp. 377–86, pls. i–iii, 1908.
[5] Rec. Geol. Surv. N.S. Wales, vol. viii, pt. iv, p. 308, pl. xlvii, 1909.

Foreign Devonian.

On the Continent the reported occurrences are, so far, equally poor. At the same time, the cursory examination which I was able to make of the thin sections of the Devonian limestones exhibited in the Brussels Museum leads me to expect that a careful investigation of the Belgian Devonian limestones will yield other examples besides *Spongiostroma*.

CARBONIFEROUS.

We now reach the period in Palæozoic times when Calcareous Algæ attained their maximum development in England, a development rivalling that which obtained in the Ordovician rocks of Scotland and the Gotlandian of the Baltic area. The genera represented include *Girvanella*, *Solenopora*, and *Mitcheldeania*, while in addition to these there occur several lime-secreting organisms which, though still undescribed, will, I think, ultimately come to be included among the Calcareous Algæ. The most interesting of these organisms I have recently figured from the Lower Carboniferous rocks of Westmorland, where it forms a definite zonal horizon or 'band'.[1] For this form, on account of its stratigraphical importance and for facility of reference, I propose the generic name of *Ortonella*.[2]

Again, at the same horizon in the North-West Province I have frequently noticed concretionary deposits of limestone which occur as finely laminated masses, the laminæ often lying parallel to the general direction of the bedding planes, which on microscopic examination show no definite or regular structure, but have every appearance of being of organic origin. Many of these puzzling forms resemble very closely the somewhat obscure structures found in the Visean limestones of the Namur basin in Belgium, of which beautiful thin sections are displayed in the Natural History Museum at Brussels,[3] and which Gürich has described and figured under various names—*Spongiostroma*, *Malacostroma*, etc., and which he has included under a new family, the Spongiostromidæ,[4] and a new order, the Spongiostromaceæ. I must confess that neither in the original sections nor in the beautiful illustrations that accompany his work can I see any grounds for referring these structures to the Protozoa.

As regards the British specimens, I have long regarded them as due, directly or indirectly, to the work of Calcareous Algæ, partly on account of their intimate association with well-developed examples of these organisms and also on account of the entire absence of Foraminifera and other detrital organisms wherever this structure occurs. As, however, I have little doubt that they are closely connected in their mode of origin with the Belgian specimens, we may conveniently speak of them under the general term *Spongiostroma*.

[1] Q.J.G.S., vol. lxviii, pl. lxvii, fig. 2, 1912.

[2] From Orton, a village between Shap and Ravenstonedale, where this organism occurs in great abundance.

[3] One of these is also exhibited at the Jermyn Street Museum.

[4] Mém. du Musée Roy. d'Hist. Nat. de Belgique, tom. iii, 1906.

Some of the best examples known to me occur associated with *Ortonella* in the '*Productus globosus* band' near the summit of the '*Athyris glabristria* zone' in the Shap district. They occur here in considerable masses, often many inches in thickness, and form undulating layers parallel to the bedding, and somewhat resembling large ripple-marks. In all cases they appear to be due to the precipitation of carbonate of lime in the neighbourhood of algal growths. I have also met with similar deposits, not only at other horizons in the Lower Carboniferous rocks of the North of England, but also in the Forest of Dean and in the rocks of the Avon Gorge; while quite recently Mr. C. H. Cunnington has sent me examples from several horizons in the Carboniferous Limestone of South Wales.

Girvanella.—This organism appears to play a considerable part in the formation of calcareous deposits in the Lower Carboniferous rocks of Britain. Its presence in these rocks was first suggested by the late Professor Nicholson,[1] who wrote: "I have found some of the Carboniferous Limestone of the North of England to contain largely an ill-preserved organism, which will, I think, prove to be referable to *Girvanella*." This prophecy has turned out to be fully justified, not only as regards the North of England, but also in the case of the Lower Carboniferous beds of other districts. In 1890 Mr. E. Wethered described[2] two new forms of this genus from the Lower Carboniferous rocks of the Avon Gorge and Tortworth, viz. *G. incrustans*, with tubes having a diameter of 0·1 mm., and *G. Ducii*, with a diameter of ·02 mm. Mr. Wethered appears to rely chiefly on the size of the tubes for the differentiation of these species, but as this distinction was made at the time when *Girvanella* was still considered to belong to the Rhizopods, and as the size of the tubes frequently varies in the same specimen, it is doubtful whether these species can be maintained. Mr. Wethered's specimens were obtained from the limestone near where the Bridge Valley Road joins the river bank, apparently at the base of Dr. Vaughan's Upper Dibunophyllum Zone. The position of this limestone is of interest, as it appears to correspond very closely with the horizon of the '*Girvanella* Nodular Bed', which forms a well-marked band at the base of the Upper Dibunophyllum Zone throughout the whole of the North and North-West of England. Indeed, I have traced this band at intervals from the neighbourhood of Ford, near the Scottish Border, southwards through Northumberland and the Pennine area to Penygent, and from the west coast at Humphrey Head through Arnside and Shap to the east coast near Dunstanburgh. These organisms must, therefore, have flourished at this period over an area of at least 3,000 square miles in the North of England alone.

The best exposure showing the important development of these *Girvanella* nodules is to be found on the dip slopes forming the eastern shore of Humphrey Head in Morecambe Bay, where the base of the Upper Dibunophyllum Zone is exposed over a considerable area.

[1] Geol. Mag., Dec. III, Vol. V, 1888.
[2] Q.J.G.S., vol. xlvii, p. 280, pl. xi, figs. 1, 2, 1890.

(*To be concluded in the December Number.*)

IV.—The Plutonic Rocks of Garabal Hill.

By B. K. N. Wyllie, M.A., B.Sc., and Alexander Scott, M.A., B.Sc., Carnegie Research Scholars in the University of Glasgow.

THIS complex of igneous rocks lies between Ardlui, at the head of Loch Lomond, and the head of Loch Fyne. In 1892 it was the subject of a fairly exhaustive paper by Teall & Dakyns,[1] but in view of a number of new facts which we have discovered we venture to submit a re-examination of the problems connected with the complex. The mass is broken by a north-east fault. The country to the west of this fault is mainly porphyritic granite and tonalite; to the east there is tonalite and also more basic diorite and ultrabasic rocks. We shall concern ourselves mainly with the basic and ultrabasic groups, as they are somewhat unusual in the "Newer Plutonic Rocks of the Highlands".

Ultrabasic Rocks.

The ultrabasic rocks form several small isolated outcrops along a line running N.N.E. from Loch Garabal, and passing about 200 yards to the east of Lochan Beinn Damhain (Loch Ben Davain). The largest of these covers about one-eighth of a square mile, and lies immediately north of Loch Garabal.

About 200 yards east of the north end of Lochan Beinn Damhain, and near a little lochan, another exposure appears, followed to the north by two others. The total area is about 200 square yards. A mere patch is also found about 100 yards south of the small lochan, and further north still, at a place 400 yards north of the highest point of Garabal Hill, a congeries of weathered blocks probably indicates another minute outcrop. The Geological Survey map of this area claims a long narrow strip, further north than our last-mentioned exposure, as peridotite. But of this no evidence was found beyond a few scattered boulders.[2] The map in the paper by Teall & Dakyns includes likewise some peninsulas and islands of schist in the plutonic rocks. A careful examination of these localities proved the outcrops to be partly schist and partly diorite, the field relations of the two, however, indicating that the schist represents the residuum of the original 'roof', which has so far escaped total denudation. A similar schist roof has been recorded by Barrow in Glen Tilt.[3] It is noteworthy that this chain of exposures is practically coincident with the line which separates the diorites from the later tonalite. But we have not been able to decide whether the ultrabasic masses are actually wedged in between these two or enveloped in the diorite close to its margin. On the diorite side

[1] "Plutonic Rocks of Garabal Hill and Meall Breac": Quart. Journ. Geol. Soc., xlviii, pp. 104–21, 1892.

[2] The sketch-map of Teall & Dakyns is reproduced in Hatch's *Petrology* (p. 303), but with the omission of all the peridotite areas we have mentioned, except the one we failed to find, while the positions of Garabal Hill and Garabal Cottage are interchanged.

[3] *Geology of Upper Strathspey*, etc. (Mem. Geol. Surv. Scotland), 1913, p. 72.

the junction is plain, but on the other side it is obscured in every instance by peat, though tonalite is exposed in mass close by and intersects both the others in dykes and strings.

The predominant type among the ultrabasic rocks is a pyroxenite, with large bronzy diallage crystals which often weather out like phenocrysts. Olivine is seldom absent; it occasionally equals the pyroxene in amount; and in places we find veins of pure serpentine, representing the end product of this replacement. All intermediate stages are found between pure olivine (serpentine) rock and pure pyroxenite. In one place an olivine-bearing rock is found forming a vein 6 inches thick in a pyroxenite.

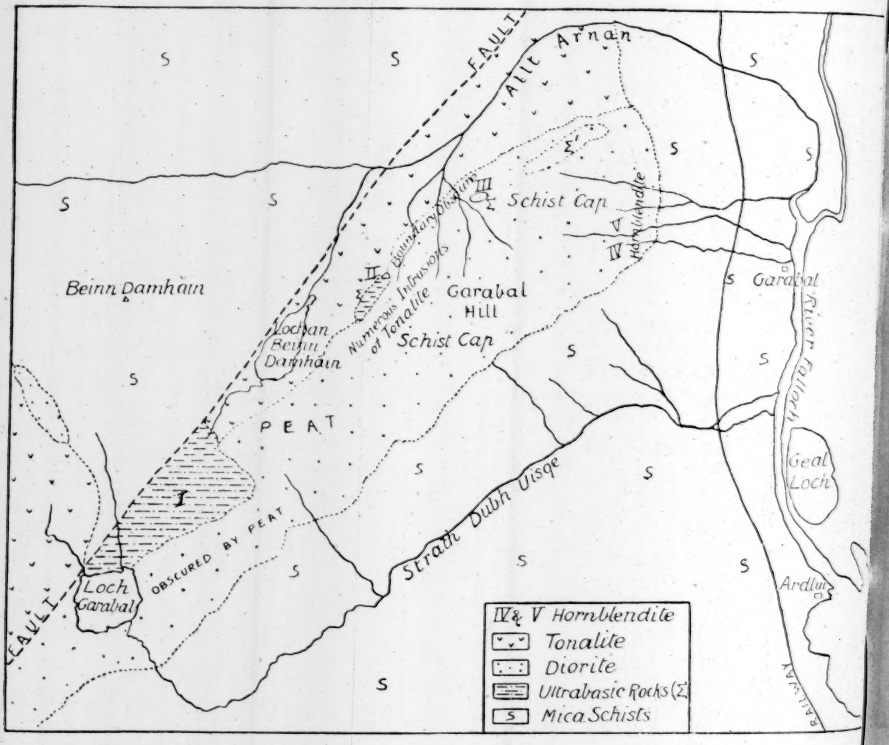

FIG. 1. Sketch-map of the basic and ultrabasic rocks of Garabal Hill. Scale 1·7 inches = 1 mile. Note: Σ′ marks the area mapped by Teall & Dakyns as peridotite, but the only evidence of peridotite that we could find was some scattered boulders.

A rock of entirely different appearance occurs in large masses at locality ii (see Map, Fig. 1) and in little strings at Loch Garabal. This is composed of glossy coal-black crystals of hornblende of a granular texture, with grains varying up to ¼ inch in diameter. At locality ii (see Fig. 1) this rock is found always intervening

between the diorite and the pyroxene-olivine rocks. It is sometimes penetrated by the diorite in such a way that the two are hard to distinguish. In thin section this rock is found to be practically a hornblende rock. The hornblende is brown, with pleochroism from dark brown to light yellow.[1] The crystals are uniform in size and packed closely together with few interstices. The cores of the crystals are very commonly of diallage, with flecks of hornblende arranged symmetrically throughout them. These pyroxene cores, again, show a sprinkling of parallel-orientated schiller rods. Even in crystals which have no colourless core these schiller patches occur, and the explanation is obvious that all the hornblende was formerly pyroxene.

Grains of rhombic pyroxene (enstatite) occur, sometimes in clusters, more often separately. Generally they are seen to be an earlier formation, the hornblende being moulded round them, or enclosing them. Interstitial felspar is scanty or absent. But veins occur which are more felspathic, the felspar then amounting to about 10 per cent of the whole. Where determinable, this felspar presents the characters of andesine. Grains of apatite are also an important accessory, and a few scattered flakes of biotite can always be distinguished.

This rock seems to be unique in Scotland, and as we have not been able to parallel it elsewhere, we propose to refer to it for the present as Davainite, which we therefore define as a rock consisting essentially of brown hornblende, which is paramorphic after pyroxene, the total amount of other minerals such as hypersthene and felspar being small. The name hornblendite we reserve for an end-member of the diorite series, to be mentioned hereafter.

The other ultrabasic rocks show, under the microscope, diallage, enstatite, olivine, brown hornblende, biotite, and black oxides, with a constant but small amount of apatite. Olivine is generally serpentinized where it is present in considerable amount. Biotite is almost always present, though never abundant. Enstatite is generally subordinate to diallage, but usually fairly abundant. Hornblende is the same brown variety described in Davainite. Here also it seems to be new-formed from pyroxene, and all stages of the replacement are found. Some specimens from the centre of the Loch Garabal mass show no hornblende. It seems to increase in amount towards the margins. Locally, a small amount of basic plagioclase (bytownite) appears.

Diallage is by far the most abundant constituent. It occurs in large crystals, giving the rock a porphyritic aspect. In one case this porphyritic structure is quite real, as the interstitial matter is granular olivine, enstatite, and smaller diallage crystals. The rock in which this is found is a vein, intrusive into a finer-grained pyroxenite, so that the phenocryst explanation is reasonable. The diallage crystals are commonly rendered dusty or dense by parallel-orientated schiller inclusions.

[1] The pleochroism of the hornblende is: X, light yellow; Y, dark brown; Z, reddish brown.

Reckoning the hornblende as equivalent to pyroxene, we may state the rock-types represented, as follows:—

PYROXENITE.
(Diallage-enstatite.)

[(Gabbro) + Norite.]

Lherzolite and Wehrlite.
(Di. En. Ol.) (Di. Ol.)

Picrite and Enstatite-picrite.
(Di. Ol. Felspar.) (Di. En. Ol. Felspar.)

Pyroxene-peridotite.
(Ol. with little Di. or En.)

Olivine rock.

We have not found any rock rich enough in felspar to be called gabbro, though the felspathic veins in davainite come very close to that. A norite has been recorded at locality iii (Map, Fig. 1), but this is a hybrid rock and will be mentioned later.

DAVAINITE.

We have now to substantiate at greater length our contention that the brown hornblende here found is altered diallage, and, consequently, that the rock we designate as davainite is the equivalent of the pyroxenites. There are two possibilities: (1) the change may have

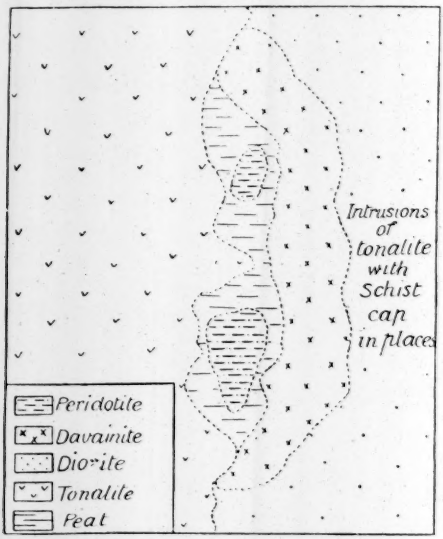

FIG. 2. Sketch-map showing the occurrence of Davainite at locality ii. (See Map, Fig. 1, *ante*, p. 500.)

occurred during cooling, and may denote a transition temperature below which hornblende is stable, and above, diallage; (2) the change may be due to some kind of annealing of the diallage rocks by the later diorite magma, which, as we have noted, is in intimate contact with the davainite at locality ii.[1] (See Map, Fig. 1.)

[1] By annealing we mean reheating to a temperature which is lower than the melting-point of pyroxene, but which lies in the region where hornblende is the stable modification.

The significant phenomena are these: (1) cored hornblende crystals, showing either actual diallage, or the diallage schiller structures, in their centres; (2) partly pleochroic diallage crystals, retaining the pyroxene cleavage and extinction; (3) amphibolized veins meandering through diallage crystals.

The last case especially can hardly be explained on the 'simultaneous' view, whereas the 'secondary' theory explains all equally well. Moreover, it may be doubted if a mere equilibrium change during the original cooling suffices to account for the formation of a strongly coloured and strongly pleochroic amphibole from a practically colourless pyroxene. Amphiboles in general are reputed to contain hydroxyl, whereas pyroxenes do not. It is possible that the introduction of hydroxyl into a molecule gives it different optical properties: for instance, amphiboles are pleochroic; pyroxenes, as a rule, are not. But the case we have at present seems to demand still more than this; it is difficult to associate the marked brown of this hornblende with anything but a marked increase in the ferric-oxide content. We suggest, therefore, that hydroxylation and oxidation have been effected by heated vapours, and general reheating, from the subsequent diorite magma.

We offer such chemical evidence as we possess in support of this idea. A specimen of davainite was analysed, but as it was more felspathic than the typical rock we have recalculated the analysis to give the proportions of the femic constituents only:—

	I.	Ia.	II.	III.	IV.	V.
SiO_2	43·53	37·00	38·6	44·94	31·84	41·01
TiO_2	1·90	2·80	—	—	—	·66
Al_2O_3	7·24	—	3·7	4·84	1·37	5·00
Cr_2O_3	—	—	—	·76	—	·14
Fe_2O_3	11·10	16·40	7·6	4·64	15·63	5·52
FeO	8·70	12·80	7·8	6·75	14·25	8·66
CaO	10·19	14·00	7·7	14·70	·91	4·43
MgO	11·51	17·00	27·7	23·16	33·10	29·92
K_2O	1·39	—	·2	—	—	·25
Na_2O	2·88	—	—	—	—	·98
H_2O+	1·34	—	} 6·4	1·48	2·49	4·95
H_2O-	·43	—				·43
CO_2	nt. fd.	—				·76
P_2O_5	trace	—	—	—	—	·10
	100·21	100·00	99·8	101·23	99·59	100·53

I. Davainite.
Ia. ,, recalculated.
II. Wehrlite (somewhat serpentinized), L. Garabal, anal. J. H. Player.[1]
III. ,, } Koswinsky Kamen, North Ural.
IV. Dunite }
V. Peridotite, Dunan Liath, Ross-shire, anal. W. Pollard.[2]

[1] Teall & Dakyns, loc. cit., p. 115.
[2] *Geology of Ben Wyvis*, etc. (Mem. Geol. Surv. Scotland), 1912, p. 127.

We note (1) that the lime content of davainite is on a par with that of the wehrlite analyses, while the comparatively low magnesia percentage is consistent with the absence of olivine. (2) The amounts of Fe O, $Ti O_2$, $Fe_2 O_3$ in davainite would correspond with 20 per cent of magnetite and ilmenite in the rock, if all were so present. But 3 or 4 per cent is all that can be allotted to these minerals. Hence it appears that the hornblende of the rock must contain a large proportion of Fe O and $Fe_2 O_3$ and probably $Ti O_2$. (3) $Fe_2 O_3$ is decidedly in excess of Fe O in davainite, which is the reverse of their normal relation in diallage-bearing rocks. We conclude that our assumption of oxidation is supported by this analysis.

We have no evidence of any considerable action on the ultrabasic rocks by the diorite magma other than this metamorphism of pyroxene: there has been no wholesale absorption, since quartz-bearing diorites are the rule close up to the contact; though the absence of olivine from the border-zone of the ultrabasic mass—at least, in all the sections of davainites we have cut—makes it possible that a slight amount of siliceous material has penetrated there. This is supported by the presence in davainite of a considerable amount of rhombic pyroxene; the clustered grains mentioned above will in that case represent original olivine. It is all the more significant that some of the rhombic pyroxene seems to be new-formed and of a different composition from that of the unchanged peridotites.

It was mentioned that among the rock-types a norite was found. This occurrence will now be described, as it is pertinent to the foregoing discussion. The rock in question forms thin irregular veins in the peridotite at locality iii (see Map, Fig. 1). In thin sections these are seen to be composed of felspar and pyroxene, with granular aplitic texture. Felspar forms about 80 per cent of the bulk except where the femic minerals are clotted together—and that always happens close to the surrounding peridotite. It consists of orthoclase, with a basic plagioclase (andesine or labradorite), the latter being far in excess of the former. In the whiter parts a few grains of quartz can be detected.

Of the femic minerals, the most striking is a richly pleochroic hypersthene, which builds large idiomorphic crystals, and is much in excess of the others, which are colourless or faintly greenish enstatite and diallage.

Now the surrounding rock is a peridotite, containing diallage and colourless non-pleochroic enstatite, with scattered flakes of mica. Diallage and enstatite in the two rocks are identical, and the vein rock presents in the same way a few stray pieces of biotite. The co-existence in the same melt of two different members of the iron-magnesium metasilicate minerals, which form a continuous series of solid solutions, is obviously impossible. Hence one of them must be xenocrystic, and that one can only be enstatite. The explanation is therefore plain: the vein rock is a hybrid, formed by partial solution of peridotite matter in a quartz-aplite, such as are abundantly associated with the later tonalite magma. Enstatite has remained unattacked. The solution of olivine has produced hypersthene, with elimination of nearly all the free silica of the solvent. Diallage has

been only partly decomposed, but that partial decomposition has set free a certain amount of lime, with the result that plagioclase is more basic than is commonly the case in aplites. It should be mentioned also that the diallage shows the usual alteration to brown hornblende, though that is not nearly so advanced as in the davainite.

When the case is considered from the purely chemical point of view, this 'selective solution' is easily understood. Olivine, being an orthosilicate, is unsaturated with respect to silica and hence would be easily attacked, the resultant product being the metasilicate, hypersthene ($Mg\ Fe\ Si_2\ O_6$). Enstatite, a metasilicate, is saturated with silica and hence remains undissolved, unless the temperature is very high. Diallage, while chiefly composed of metasilicate molecules, also contains compounds of the type $R''\ Al_2\ Si\ O_6$, and these can take up more silica to form types such as $R''\ Al_2\ Si_2\ O_6$. Thus the formation of anorthite, and consequent basification of the plagioclase, may be expressed by the equation

$$Ca\ Al_2\ Si\ O_6 + Si\ O_2 \longrightarrow Ca\ Al_2\ Si_2\ O_8.$$

Tonalite and Diorite.

Garabal Hill itself is composed of a series much more acid than those described above. There are clearly two separate rock masses, the earlier one comprising diorites with a considerable variety of structure and mineralogical composition, while the later one is a more or less uniform tonalite. The latter is obviously intrusive into the former, as it penetrates both the diorites and davainites in numerous veins of varying thickness, and generally with sharp junctions and no commingling on the margins. The tonalite consists mainly of deep-brown strongly pleochroic biotite and zoned oligoclase in a matrix of quartz, orthoclase, and plagioclase. The quartz and felspar contain numerous inclusions of apatite, zircon, and sphene, while in the ground-mass sporadic crystals of sphene and muscovite are found. In the region of Garabal Hill the rock is even-grained and not particularly coarse, although in one or two places mica 'clots' are found, consisting of aggregates of biotite, with strong absorption, and subordinate interstitial quartz and felspar. These probably represent foreign material which has been absorbed and completely recrystallized. Near Meall Breac, to the west of the fault and in the area mapped by the Geological Survey as tonalite, a much coarser rock is found. It differs from the tonalite described above, not only in texture but also by the presence of green hornblende, equalling in amount the biotite, and of fairly large crystals of sphene. It closely resembles some of the more acid diorites and should probably be classed with them.

The diorites differ considerably in the different localities, and grade from fairly acid, quartz-bearing rocks to pyroxene diorites and hornblendites. The chief constituent minerals are quartz, orthoclase, plagioclase, mica, hornblende, pyroxene and sphene. The plagioclase in the more basic varieties is labradorite-andesine, but oligoclase is found in the 'acid' rocks. The quartz and felspar are rich in inclusions of apatite, zircon, and occasionally rutile. The mica is generally biotite with strong pleochroism and absorption, and often

altering to chlorite. Sphene occurs in pleochroic yellow crystals as well as in the common granular form.

The pyroxene is a pale-green diopside with an extinction of 30°–40° and showing generally schiller inclusions. Occasionally aluminous pyroxenes are also found. The amphibole is the common green hornblende with low extinction and strong pleochroism from light to dark green. It occurs partly as the margins of pyroxene crystals, or as a paramorphic replacement of these, and partly as original crystals. It undergoes alteration in two ways, sometimes to aggregates of pale-coloured actinolite, sometimes to a brown hornblende with a complicated pseudo-schiller structure, which will be described later.

One of the more acid types occurs on the south-east slopes of Garabal Hill, and consists of quartz, felspar, and green hornblende, with subordinate biotite, and chlorite. The felspathic minerals greatly preponderate, though the amount of quartz is comparatively small. Sphene is common, and is usually altering to ilmenite or leucoxene. A much coarser rock with abundant sphene and apatite, and no quartz or biotite, is found to the east of Loch Garabal. The felspar is nearly all saussuritized, while the original hornblende is replaced by fibrous aggregates of actinolite or tremolite. Occasionally traces of original pyroxene cores surrounded by paramorphic hornblende are found. In places this passes to a quartz-bearing rock with a fair amount of biotite, while the hornblende assumes a more prismatic habit than usual. This rock is probably some kind of 'schlieren', as it is more acid than the surrounding rocks, and at other localities, which will be described later, obvious schlieren are found, containing amphibole of similar habit. The diorite which forms the eastern margin of the main davainite area somewhat resembles the Loch Garabal rock. It is finer in grain than the latter, but the felspar is partly replaced by saussurite and the hornblende by actinolite. Quartz is absent, while the presence of original pyroxene is indicated by hornblende aggregates containing traces of original diallage or diopside. A few small flakes of biotite, which is probably secondary, are also present. On the ridge north of Garabal Hill a rock occurs which seems to be the most basic of the diorites; it probably approaches a gabbro in chemical composition. It is a medium to coarse-grained aggregate of plagioclase, hornblende, and pyroxene, with subordinate orthoclase and biotite and no quartz. The felspar is a comparatively unaltered labradorite exhibiting good twinning, while the hornblende is a green mineral more or less completely altered to brown, and the pyroxene is the pale-green diopside common to the diorites. The felspar occurs in coarsely granular aggregates filling up the interstices between the ferromagnesian minerals. Mineralogically the rock might also be described as a hornblende-gabbro.

In the neighbourhood of loc. iii (see Map, Fig. 1) numerous veins and clots occur, rich in epidote. Sections were made of specimens from one such vein which showed some considerable variety. The centre of the vein consisted of epidote, vesuvianite, and spinel, with occasional crystals of hornblende. The epidote occurs as an even-grained mass of subhedral crystals with pleochroism from yellow to

pale-green and somewhat larger in size than the crystals found in similar veins in Cornwall. Minute crystals of blue magnesia-bearing spinel are found bordering the epidote. In the centre rock the vesuvianite occurs interstitially, and is obviously the last mineral to crystallize, but towards the margins aggregates of large hornblende and idocrase crystals occur, both being subhedral. The vesuvianite crystals are brownish to colourless, with occasional lamellar cleavage and the characteristic low double refraction. The amphibole resembles the green hornblende of the diorite, but is obviously changed in places to a mineral resembling glaucophane, while elsewhere epidote and vesuvianite have developed at its expense, the crystals being very much corroded round the margin. The vein is bordered by a narrow band of typical hornblende schist, consisting of blue-green amphibole, quartz, orthoclase, and albite, with occasional patches of the original dioritic hornblende in a state of partial alteration.

Epidosites have been described by the Geological Survey from both sedimentary and igneous schists and gneisses in the Lizard district[1] and also from the Kilmartin district, where they occur in epidiorites.[2] Those occurring in the sedimentary rocks are generally quartzose, and are probably produced by the shearing of rocks which were weathered before being metamorphosed. The 'igneous' epidosites, however, are assumed to be due to chemical segregation during movement, and it is this explanation which seems to be most applicable in the case of the Garabal Hill rock. The epidote rocks of the latter area differ from those of Cornwall by the almost complete absence of minerals other than the lime-bearing ones—the amount of spinel is exceedingly small. They seem to have formed along shearing planes in the diorite, where the country rock has undergone strain of such intensity that it has been rendered completely fluid.[3] The neighbouring rock is a hornblende-pyroxene-diorite with a basic plagioclase as the only felspathic mineral. The shearing has resulted in chemical interaction between the felspar and the ferromagnesian minerals, with the formation of epidote. Several cases of the production of epidote as a contact mineral between felspar and hornblende[4] have been recorded, and it seems probable that the reaction between these two minerals in a fluid state in presence of water is comparatively simple. The crystals on the margins would be easily attacked, the large hornblendes which are partly corroded being those which have been incompletely dissolved. This solution effect would also explain the partial aggregation of the vesuvianite at the margins, as the latter is richer in lime and poorer in alumina than epidote, while hornblende is

[1] Flett in *Geology of Lizard and Meneage* (Mem. Geol. Surv. England), 1912, pp. 36, 46.

[2] Flett in *Geology of Seaboard, Mid-Argyll* (Mem. Geol. Surv. Scotland), 1909, pp. 47–50.

[3] At several other places on Garabal Hill evidence of faulting is found; thus at loc. iv (see Map, Fig. 1) a line of brecciated diorite with numerous quartz-veins can be traced for about 20 yards.

[4] G. H. Williams, Bull. U.S. Geol. Surv., 1886, No. 28, p. 31; F. D. Chester, Bull., 1890, No. 58, p. 35.

likewise richer in lime and poorer in alumina than felspar. The vesuvianite aggregates, therefore, are the product of the solution of hornblende crystals in a fluid so viscous that but little diffusion could take place. The interstitial vesuvianite arises through a combination of two causes: (1) The ratio of lime to alumina in the diorite is, as stated above, higher than that required for the formation of epidote. (2) The diorites contain appreciable amounts of magnesia and alkalis. Part of the former crystallizes as spinel, but the remainder, together with the alkalis, would enter the vesuvianite molecule, which can have up to 6 per cent magnesia and 2 per cent alkalis, while epidote rarely has more than a trace of either.

(*To be concluded in our next Number.*)

V.—On Saturated and Unsaturated Igneous Rocks.

By Professor S. J. Shand, D.Sc., Ph.D., F.G.S., Victoria College, Stellenbosch, South Africa.

Of the various minerals which enter into the composition of igneous rocks, about one-half are capable of forming in presence of free silica, as is shown by their association in rocks with quartz and tridymite. These may, for the present purpose, be termed *saturated* minerals; they include some of the most highly silicated compounds of their respective metallic elements. The remaining rock minerals do not appear in association with free silica, and may be presumed to be incapable of stable existence in its presence; they are mostly the less highly silicated compounds of the same metallic elements which enter into the former group. These may, for the present purpose, be termed *unsaturated* minerals. The unsaturated character of any mineral in the latter group is not affected by the temperature and pressure at which crystallization takes place; this is shown by the fact that quartz and the minerals referred to are mutually exclusive both in plutonic and in effusive rocks. In the case of sodium, potassium, calcium, and magnesium the formation of saturated or unsaturated minerals appears to depend only on the amount of silica available in the magma. Aluminium, ferrosum, and ferricum, elements of feebly basic character, have their combinations largely determined for them by the more strongly basic elements, with which they tend to form either complex molecules or mix-crystals.

In the following table the saturated and unsaturated compounds of each element are placed as far as possible in apposition:—

Saturated.	*Unsaturated.*
Orthoclase.	Leucite.
Albite.	Nephelite.
	Sodalite.
	Nosean.
	Analcite.
	Cancrinite.
Anorthite.	Hauyne.
	Melanite.
	Melilite.
Pyroxenes.	Olivine.
Amphiboles.	Pyrope.
Micas.	Picotite.

Saturated.	*Unsaturated.*
Tourmaline.	
Spessartite.	
Topaz.	Corundum.
Titanite.	Perovskite.
Magnetite.	
Ilmenite.	
Apatite.	
Zircon.	

I anticipate that objection may be raised to one or two of the minerals classed here as unsaturated. The first of these is olivine. A few dolerites and basalts have been described as containing both quartz and olivine, but I think the experience of most petrographers will show that this association is quite unusual. I have never come across an instance of it in the field, and I think it highly probable that the explanation of such an unusual association is that the quartz is not of magmatic origin. The only example of a quartz-olivine rock in my collection is the 'melaphyre' of Albersweiler in the Rhenish Palatinate, which contains small 'phenocrysts' of quartz. An examination of this rock decidedly suggests that the supposed phenocrysts are really xenocrysts. They are just as often aggregates as single grains, and they are always anhedral, with rounded, fretted outlines. But to be sure of this one would require to study the rock in the field. Harker[1] and Mennell[2] have both described occurrences of quartz xenocrysts within basalts and dolerites. In the cases described by Harker, basalt sills which were invaded by granophyre have been acidified and impregnated with quartz xenocrysts by the latter. In the dolerite intrusions in the Matopo granite, which Mennell describes, the quartz xenocrysts and the interstitial micropegmatite of the dolerites are due to absorption of granite. In at least one of these intrusions olivine is present. As the latter is a mineral of very early crystallization it is evident that the absorption or incorporation of quartz may occur too late to prevent the partial separation of magnesium in the form of olivine, and hence the two minerals may exist side by side. According to this view such quartz-bearing dolerites would be hybrid rocks, not true magmatic products. For further evidence bearing upon this point I must await the judgment of those who have the opportunity of studying such exceptional rocks in the field.

As regards corundum, I know of no instance where it occurs in association with quartz in igneous rocks; its common hosts are nephelite-syenites, anorthosites, and peridotites. Any excess of alumina over bases in the quartz-bearing rocks always seems to appear as muscovite or topaz, not as corundum.

It may seem strange that garnets should fall into two contrasted groups, the spessartites (and probably the almandites as well) being regarded as saturated while others (melanite, pyrope) are unsaturated; yet this is simply an expression of observed facts of distribution. In my own experience of melanite rocks in Sutherlandshire,[3] where

[1] *Tertiary Igneous Rocks of Skye* (Mem. Geol. Surv., 1904).
[2] "Basic Dykes and Rock Genesis": GEOL. MAG., 1911.
[3] Trans. Edinb. Geol. Soc., 1910.

quartz syenites pass insensibly into melanite syenites, the first trace of melanite does not appear until the last trace of quartz has been lost, although there is no immediate change in total lime content.

Anorthite, too, appears at first sight to occupy an anomalous position; it is an orthosilicate occurring in a group which is mainly composed of polysilicates and metasilicates. But calcium metasilicate (wollastonite) is incapable of independent existence under magmatic conditions, hence the orthosilicate is the stable form even in quartz-bearing rocks. True quartz-anorthite rocks are probably rare, but the anorthite molecule must have been present as such in the parent magma of every quartz-plagioclase rock.

Magnetite and ilmenite are of course completely unsaturated as regards silica, from the chemical point of view, but as both are capable of stable existence in the presence of free silica under magmatic conditions, they rank here as saturated minerals. (Should it be felt that this new use of a common term is liable to be misunderstood, the reader may at his pleasure read *sated* and *unsated* in place of 'saturated' and 'unsaturated'.)

A rock which contains only saturated minerals may be termed a *saturated rock*; one which contains only unsaturated minerals may be termed an *unsaturated rock*. It will also be desirable to distinguish *partsaturated rocks* (e.g. phonolites, olivine-dolerites) from wholly unsaturated ones; as a general term to cover both partsaturation and unsaturation we may employ *undersaturation*. Any rock which contains free quartz or tridymite of magmatic origin will be termed *oversaturated*.

These distinctions are by no means trivial; they have a very definite chemical significance which has a bearing upon the reaction of the magma towards invaded rock masses, and hence upon magmatic differentiation. They are also capable of useful application in the classification of igneous rocks.

1. An undersaturated magma (i.e. one which on solidifying would give rise to a partsaturated or unsaturated rock) is capable of entering into chemical combination with the silica of invaded rock masses. The reactions thereby induced would be exothermic, and would tend to raise the temperature of the magma. The amount of heat to be gained in this way does not seem to be susceptible of direct measurement at the present time: the difficulties to be overcome would be very great, but as silicic acid is known to be an exceedingly powerful acid at high temperatures, it is probable that the heating effect of the reaction would be considerable. The access of heat produced in this way would in turn enable the magma to perform a further amount of work in the way of mechanical solution.

2. A saturated or oversaturated magma (i.e. one which on solidifying would give rise to a saturated or oversaturated rock) is incapable of combining chemically with silica; its action on the quartz of invaded rocks must be confined to physical solution, which will lower the temperature of the magma.

Other things being equal, then, an undersaturated magma must have a greater action upon invaded siliceous rocks than a saturated or oversaturated magma; as a result of such action it would tend

first to saturate itself chemically, then to oversaturate itself in the physical way. (Reactions with constituents other than silica are for the moment disregarded.) As a consequence of the greater activity of an undersaturated magma, one would expect to find greater variation, both chemical and mineralogical, within a body or complex of undersaturated rocks than in a saturated or oversaturated body or complex. This deduction seems to be confirmed by the enormous number of varietal names which have been coined for different facies of the undersaturated rocks.

3. Towards the aluminous constituents of invaded rocks it would seem that there would be little difference in the behaviour of saturated and undersaturated magmas. The change by which aluminium silicates are converted into micas and felspars, a change for which the field evidence is overwhelming in amount, could not be effected any more readily by a felspathoidal magma than by a felspathic one, since in both felspars and felspathoids the ratio of Na, K : Al is the same. This particular conversion must be due to an excess of alkali in the magma, of which no trace remains as such when the rock has solidified and become exposed to investigation. With this point, however, I am not at present concerned. There remains the theoretical possibility that aluminium silicates might be reduced to corundum by reaction with an undersaturated magma.

4. When the invaded rock is a carbonate or other non-silicate rock, or contains much lime, magnesia, or iron in the form of oxide or carbonate, then the advantage as regards absorbing power lies with the saturated and oversaturated magmas, which can yield first their excess of silica, and secondly a further quantity of silica due to the reduction of sodium, potassium, calcium, and magnesium molecules from the saturated to the unsaturated state. In this way a saturated or oversaturated magma may become undersaturated. This case, as regards alkaline rocks, has been presented by R. A. Daly.[1]

The above deductions involve no assumption at all as to the *extent* to which absorption takes place in nature; so long as even a few instances arise in which absorption is admitted to have taken place, then it becomes necessary to recognize the essential difference in the absorptive capacity of saturated and undersaturated magmas. The appearance of, let us say, nephelite in a syenitic rock means far more than the mere addition of another name to the list of accessory minerals present in the rock; it involves a real difference, both of kind and degree, in the reaction of the magma towards its environment. By studying the distribution of the saturated and undersaturated members of an igneous complex one may gain a wider view of the process of differentiation than is to be had from the study of minute mineral and chemical differences alone.

With these considerations in view, it is instructive to turn to the distribution of oversaturated and undersaturated rocks in the lithosphere.

1. As regards mere bulk, the oversaturated and saturated rocks predominate enormously over the undersaturated. Daly[1] estimates

[1] "Origin of the Alkaline Rocks": Bull. Geol. Soc. Amer., 1910.

that "all the visible alkaline rock of the world probably constitutes less than 1 per cent of the total visible igneous rock". If in addition to the alkaline rocks we consider the olivine, melilite, melanite, and corundum-bearing rocks, it seems likely that the total mass of the undersaturated rocks will scarcely exceed 2 per cent of the total visible igneous rock.

2. Among major intrusions the vast majority consists of oversaturated rocks. Saturated rocks have a much smaller representation, and undersaturated rocks are relatively rare except as marginal facies and differentiated bodies. Where nephelite-syenites occur they are in surprisingly many cases associated with limestones, and Daly[1] makes out a good case for regarding some of them, at all events, as due to absorption of limestone. Thoroughly unsaturated types (e.g. dunite) never form truly major intrusions.

3. Among lavas and minor intrusions the oversaturated types are quite subordinate to the saturated and undersaturated. Thoroughly unsaturated types, though rare, are recognized in dunites and some monchiquites and alnöites. Undersaturated types, such as nephelite and leucite tephrites, basanites, and basalts, olivine dolerites and basalts, picrites, peridotites, and serpentines, are well represented.

4. A curious point, which will, I think, survive the test of statistics, is the very frequent occurrence of undersaturated and unsaturated rocks in the pipes of single-explosion volcanoes. The olivine bombs of the Dreiser Weiher and other volcanoes of the Eifel and Auvergne, and the ultrabasic agglomerate with content of olivine and pyrope which fills the pipes of some of the volcanic necks of Scotland, will serve to illustrate this point, but the most superb examples are the kimberlite and alnöite pipes of South Africa. Kimberlite, with its abundant olivine and pyrope, and its possible melilite,[2] is emphatically undersaturated; while some of the alnöites, as described by Rogers,[3] are entirely unsaturated.

These observations can be reduced to the following form: Those igneous rocks which have been brought up most rapidly from the earth's interior, and have solidified most rapidly in or on the crust, are to a marked extent undersaturated. Those others which have slowly worked their way up into the crust (and have hence had abundant opportunity for absorbing silica) are found to be predominantly oversaturated. We have here a strong suggestion that undersaturation may be characteristic of the deeper zones of the lithosphere, as oversaturation is of the higher. I do not wish to insist upon this point, but merely to show that the distinctions employed here have their uses even in the discussion of the major problems of geochemistry.

The conceptions of saturation and undersaturation are capable of application to the classification of igneous rocks, and provide just those natural distinctions between different types, the absence of which petrographers have been accustomed to deplore. If writers

[1] "Origin of the Alkaline Rocks": Bull. Geol. Soc. Amer., 1910.

[2] Carvill Lewis, 1897; Mennell, 1909.

[3] Trans. S.A. Phil. Soc., 1904; Ann. Rep. Geol. Comm. (Cape of Good Hope), 1911.

like Dr. Hatch[1] and Mr. Mennell,[2] who tie their faith to silica percentages, would instead employ the mineralogical dividing lines which separate the oversaturated from the saturated rocks, and these again from those which are undersaturated (1) with regard to leucocratic constituents, (2) with regard to melanocratic constituents, and from (3) those which are undersaturated or unsaturated in all their constituents, they would find themselves in possession of a much more 'natural' classification of rocks, and one which would be vastly simpler to use than any classification which is based upon silica percentages. The connexion between mineral and chemical composition need not be obscured thereby, but rather the reverse, especially if, as could easily be done, the relative degrees of oversaturation or undersaturation were introduced as subordinate factors in the classification. The fact that, under different conditions of temperature and pressure, one and the same magma may give rise to rocks of different degrees of saturation, is an argument in favour of my contention, not against it. The classical experiment of Fouqué and Michel-Lévy, in which a melt of orthoclase and biotite yielded leucite and olivine on cooling, illustrates this point. The silica percentage, being the same in the product as in the educt, fails to express the difference between these two very different mineral associations; yet the former is saturated, the latter unsaturated, and by making degree of saturation a criterion of systematic position we effect a separation of things formed under unlike conditions, which is at least as important as the separation of things of unlike ultimate composition.

If Dr. Hatch and Mr. Mennell had considered the natural criterion of undersaturation, in place of the artificial one of silica percentage, they would not have been led into the paradoxical positions of classifying borolanite, a rock which typically contains neither plagioclase nor augite, with "alkali-gabbro" and "dolerite" respectively. In my opinion both these gentlemen have erred by committing themselves to classifications which are neither definitely chemical nor definitely mineralogical. A chemical classification, to be of any value, must have regard to *all* the molecules present in a rock, not to one alone. If a classification is to be mineralogical, let it be consistently so. I believe that both chemical and mineralogical classifications are necessary, but of hybrid classifications I would go so far as to say, as Harker says of hybrid rocks, "like other hybrids, they are barren."

The recognition of the essential difference between saturated and undersaturated rocks ought to lead to the avoidance of such loosely-used terms as shonkinite, monzonite, and essexite. We read in Dr. Hatch's textbook, for example, that "nepheline and leucite occur occasionally in monzonites"; that essexites contain a variable quantity of nepheline; and that nepheline and sodalite "may be present in small quantities" in shonkinite. The older petrographers always drew a sharp distinction between the syenites and the nepheline-syenites; however small the proportion of nepheline, it was considered sufficient to justify the removal of the rock from the former to the

[1] *Textbook of Petrology*, 1909. [2] *Manual of Petrology*, 1913.

latter class. The same procedure, with regard to olivine, is followed to this day in the application of the names tephrite and basanite, nephelinite and nepheline basalt. The distinction between the saturated and the unsaturated minerals is a real one, with important consequences in the chemistry of rock magmas; and petrographers who shut their eyes to a natural distinction of this kind deserve the fate that awaits them at the hands of inventors of arbitrary classifications.

The present paper is an argument for the importance of the above distinction, and a plea for its recognition in petrographic nomenclature.

VI.—Septaria: a Defence of the 'Shrinkage' view.

By T. Crook, A.R.C.Sc. (Dublin), F.G.S.

A CONTRIBUTION to the March number of the Geological Magazine by Dr. A. M. Davies, and another in the August number by Mr. J. E. Todd, support a view formerly held by Professor H. G. Seeley, viz. that the cracks of septaria are due to expansion, during growth, of the outer layer of the nodule.

For several reasons this view appears to me to be untenable. It seems to be based on an erroneous conception of what takes place during the growth of a septarian nodule. It exaggerates the significance of crystallizing force in material deposited from solution. In a rudimentary way a nodule is a crystalline growth, but the manner of this growth speaks of a force of crystallization that has been thwarted and not allowed free play. A nodule is of the nature of an imperfectly crystalline precipitate, rather than a robust crystalline growth. It consists of a mass of shapeless microcrystalline granules, each of which was presumably deposited from solution in such a way as to accommodate itself quietly to the surface on which it grew. Surely Mr. Todd makes a mistake when he compares the crystallizing force of material deposited from solution to the expansive force manifested by water in solidifying. There is no analogy between the two processes.

I think we are justified in asserting that the growth of a septarian nodule in a clay has at least this in common with the growth of a crystal from solution: it presents a sharply defined surface to the medium in which it is growing, and it grows by addition of material to the surface. And if material can be deposited on the faces of a growing crystal without the interior being ruptured by the crystallizing force when that force displays its full vigour, why should the addition of shapeless and accommodating microcrystalline granules to the surface of a growing nodule result in internal rupture?

Moreover, nodules are septarian only when they have incorporated within their substance a considerable amount of colloidal clayey matter. If a nodule consists of fairly pure carbonate, or if it contains sandy matter to the exclusion of clay substance, it does not become septarian. How is this fact explained by the 'expansion' view?

Again, I fail to see how we can allow the last added shell of the nodule to crack the enclosed mass without cracking itself; and if the outer shell did expand during growth without cracking itself,

the process would probably result in a series of concentric cracks infilled with calcite, rather than in radiating cracks. There is really no evidence that the cracks develop during growth in this way; and until some proof is forthcoming that crystallizing force acts in the way suggested, it seems more reasonable to adopt the view that the cracks arise from shrinkage subsequent to growth. This shrinkage view seems to be well in accordance with the facts, and accounts for the results in a more satisfactory manner.

In explaining the formation of the cracks by shrinkage, it is important to note that the rate of radial growth of a nodule probably diminishes very rapidly as the nodule increases in size. If we assume, for the sake of argument, that its shape is spherical, then the surface area of the growing nodule increases as the square of the radius. It follows, therefore, that the surface of deposition when the nodule is 10 cm. in diameter is 10,000 times greater than it was when the diameter was 1 mm., and 100 times greater than it was when the nodule had a diameter of 1 cm.

Not only is there this tremendous rate of increase in the surface of deposition during the growth of the nodules: there is also a decrease in the dissolving surface; for the particles of less stable carbonate from which the solution maintains its supply are continually diminishing in size as the nodules grow. Until the contrary is proved, it is reasonable to infer from these facts that the rate of radial growth diminishes enormously as the nodule increases in size. If so, its substance during growth will gradually increase in compactness from the centre outward; and the last-formed layers will probably be very much more compact than the first-formed layers.

We should expect that the first-formed part of a nodule would incorporate more argillaceous material than the portions formed later. Mr. Todd states that this is not the case; but his statement is not convincing. At least we may assume that the argillaceous material of the earlier-formed portion is much wetter than that of the later-formed portion of the nodule.

We may still conclude, therefore, that the internal mass of the nodule consists of wet argillaceous carbonate, and that it is surrounded by an outer shell of drier and more compact material. The nodule in this state will, like the enclosing sediment, continue to suffer from the compacting process. It will lose water, and shrink. The more compact outer shell will suffer little tangential contraction. The contraction of the wetter interior will be more considerable, and will be accommodated by a shrinkage of the mass on the outer shell. This will result in the development of radiating cracks, which may ultimately become filled with calcite.

I see nothing in the facts so far adduced that invalidates this explanation. It is singular that so little has been done in the way of investigating the facts bearing on this subject, and that so much has been left to speculation. Until a fuller investigation has strengthened the case against it, I for one shall continue to hold the 'shrinkage' view.

NOTICES OF MEMOIRS.

Abstracts of Papers read in Section C (Geology), Meeting of British Association, Birmingham, September 10–17, 1913.

1. On various Occurrences of Pillow Lavas in North and South Wales. By A. Hubert Cox, M.Sc., Ph.D., F.G.S., and Professor O. T. Jones, M.A., D.Sc., F.G.S.

Pillow lavas were described from four localities, viz.:—

(*a*) Strumble Head, in Pembrokeshire.
(*b*) Cader Idris, in Merionethshire.
(*c*) Sarn Mellteyrn, near Pwllheli, Carnarvonshire.
(*d*) Careg, 2 miles N.N.W. of Aberdaron, Carnarvonshire.

(*a*) Strumble Head (A. H. Cox).—References were made particularly to the work of Reed and Elsden. The rocks were formerly regarded as intrusive, and were described as of composite characters and possibly of later date than the main folding.

Variolitic rocks were described by Reed, who referred to the 'pillow structure' as 'spheroidal jointing'. The whole mass appears to consist largely of highly vesicular, basic flows, some with well-developed pillow structure, others showing transitions to non-pillowy types. Abundant chert occurs in association with the lavas, particularly those showing pronounced pillow structure. The most perfect pillows vary from a foot to 18 inches in diameter, and consist of typical spilites, with thin, rod-like felspars of refractive index about 1·542, corresponding to oligoclase—the rocks are considerably decomposed, especially to calcite, chlorite, and epidote.

Among the above rocks are ophitic diabases, showing marked columnar jointing, which may in part represent sills.

(*b*) Cader Idris (A. H. Cox).—A thick band of pillow lavas forms the highest point of the Cader Idris range, and then strikes W.S.W. Its distribution is described in detail, and reference is made to the work of Ramsay and Geikie. A comparison of these rocks with those of Strumble Head discloses certain differences, especially in their uniformly less vesicular character and smaller amount of associated chert. Under the microscope the rock shows the character of a typical spilite; both rod- and lath-shaped felspars occur, the former being oligoclase, the latter somewhat richer in soda (refractive index below 1·541). The rock is considered to resemble most closely that of Mullion Island. In close association with it is the 'Eurite' (soda-granophyre) of Cole and Jennings. These lavas appear to occupy a stratigraphically higher horizon than the beds which yielded *Didymograptus bifidus* and *D. murchisoni* to Lake and Reynolds. The detailed examination of the area is still incomplete.

(*c*) Sarn Mellteyrn (O. T. Jones).—References were made to the work of various authors, viz. Ramsay, Harker, Raisin, Elsden, Matley.

The rocks are exposed by the roadside three-eighths of a mile south-west of Mellteyrn Church, where 10 to 12 feet of typical pillow lavas overlain by a similar thickness mainly of non-pillowy rocks of allied characters are followed by flinty mudstones and micaceous shales.

The spaces between the pillows are occupied by closely-jointed dark-grey chert. The sediments dip to the east at a moderate angle, and probably pertain to the lower part of the Arenig. The pillow lava is finely vesicular and considerably decomposed; the felspar is oligoclase and forms lath-shaped microliths. From its structure and mineralogical character the rock is referred to the spilitic suite.

(*d*) Careg, near Aberdaron (O. T. Jones).—These rocks have been described in detail by Raisin, and the pillow structure noted as 'spheroidal structure'. The present notes are intended to supplement that description in certain respects.

The pillow structure is seen near Careg quarries and near the coast; individual pillows have a length of about 2 feet, and are composed of a fine-grained rock with small vesicles. The felspars have the extinction-angle and refractive index of oligoclase-albite, and are highly charged with decomposition products. These rocks are undoubted spilites, and were claimed as such by Dewey and Flett; they are associated with 'limestones' of a peculiar character, together with beds and strings of jasper, which in places wrap round the pillows in the same manner as the chert near Sarn. The association of that rock with a pillow lava may perhaps be regarded as confirming Greenly's suggestion that the jaspers of Anglesey were originally cherts. The associated rocks at Careg have an extraordinarily complicated structure, and probably belong to the pre-Cambrian.

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2. Critical Sections of the Cambrian Area called the Cwms in the Caradoc–Comley Region of Shropshire. By E. S. Cobbold, F.G.S.

THE work of excavation of critical sections in the Cambrian rocks of Shropshire has been continued by the writer at intervals during the past year, and has furnished palæontological proofs of the prolongation of the Lower and Middle Cambrian rocks of Comley into the Cwms area to the south. The sections opened up confirm and amplify those excavated in previous years.

Excavation No. 53 supplies details of the upper portion of the Wrekin Quartzite and the lowest part of the Lower Comley Sandstone, near the base of which three fossiliferous bands are found, yielding species provisionally referred to *Kutorgina*, *Hyolithus*, *Hyolithellus*, and *Archæocyathus*.

Excavation No. 54 exhibits a section of the junction of the Middle and Lower Cambrian beds, which is very closely comparable with those of the Quarry Ridge at Comley.

The beds in descending order are as follows:—

		ft.
e.	Shale with Grit Bands = The Quarry Ridge Shale, top not seen	4
d.	Hard, ringing, glauconitic Grit = The Quarry Ridge Grit	28
c.	Conglomerate = The Quarry Ridge Grit, conglomeratic portion	9
b.	Dark Grey, Purplish, and Red Limestones = The Black, Grey, and *Olenellus* Limestones of Comley	about 4
a.	Green, Micaceous Sandstones, with spotted bands = The Lower Comley Sandstone; base not seen	10

The conglomerate *c* is plentifully charged with fragments of the Black and other Lower Cambrian Limestones, and it is now proved for the first time that the Black Limestone must be grouped with the Lower Cambrian.

The surface of the solid Black Limestone is coated with a phosphatic (?) skin, and a similar deposit in the Comley Quarry has within the last two or three years yielded recognizable fragments of *Paradoxides* sp. and *Dorypyge Lakei*, Cobbold. The black skin must, therefore, be regarded as the lowest deposit of the Middle Cambrian age that is known in the district.

Among the numerous fossil fragments that occur in the Lower Cambrian Limestones of this excavation the following have been identified: *Anomocare* (?) *pustulatum*, Cobbold, *Callavia Callavei*, Lapworth (?), *Microdiscus Attleborensis*, S. & F., sp., *Protolenus* sp., *Kutorgina* sp., *Linnarssonia* (?) sp.

Excavation No. 55 exhibits a faulted junction between the Middle and Lower Cambrian, the hard, ringing Grit (beds *d* above) being brought into contact with the Green, Micaceous Sandstone (beds *a* above).

Excavation No. 56 proved the existence of both the Quartzite and the lower part of the Lower Comley Sandstone at another point in the area.

A section constructed embodying the results of these excavations provides evidence that the Lower Comley Sandstone has a thickness of about 480 feet.

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3. *Estheria* in the Bunter of South Staffordshire.[1] By T. C. Cantrill, B.Sc., F.G.S.

RECORDS of fossils in the British Bunter are few in number, and some are open to doubt in respect either of their organic character or of the stratigraphical position of the beds that yielded them. Omitting those cases where the horizon formerly supposed to be Bunter has been corrected later and is now accepted as settled, the following appears to be a complete list, in chronological order of their discovery:—

1. *Dictyopyge catoptera* (Ag.), a small fish, from Rhone Hill, 3 miles south-east of Dungannon, co. Tyrone. Upper Bunter (f^2). With this was associated *Estheria portlocki*.

2. 'Annelid tracks' at Hilbre Point, Wirral, Cheshire. Lower part of the Bunter Pebble Bed (f^2).

3. Plant-remains, referred to *Schizoneura paradoxa*, Schimper and Mougeot, at Sneinton Vale, near Nottingham. Uppermost bed of the Bunter Pebble Bed (f^2).

To these three older records can now be added the following new discovery[1]:—

4. *Estheria* cf. *minuta* (Alberti), from Ogley Hay, near Walsall, South Staffordshire. Bunter Pebble Bed (f^2).

[1] Communicated by permission of the Director of the Geological Survey.

These fossils were discovered in May, 1911, when Mr. C. H. Cunnington and I were mapping the Triassic rocks bordering the eastern side of the coal-field. I suggested to my colleague that if fossils could be found anywhere in the Bunter they would most likely be discovered in the thin marl-bands occasionally interbedded in the predominant sandstones and conglomerates; and Mr. Cunnington's hammer was the first to reveal the specimens.

We obtained them from two thin bands of red marl in a disused sand-quarry at Ogley Hay, 5 miles north-east of Walsall. The quarry forms a conspicuous excavation in the northern face of a sandstone hill, along the foot of which passes the Anglesey branch of the Wyrley and Essington Canal. The hamlet of New Town, on the Watling Street, lies 150 yards to the north of the quarry, while Ogley Hay Chemical Works stands 200 yards away to the south-east. Below a little drift gravel are exposed 22 feet of dull-red medium-grained soft sand-rock, in places false-bedded. Toward the bottom are two bands of red marl, about 1 ft. 8 in. apart, the lower one being about 2 feet above the bottom. They nowhere exceed 9 inches in thickness. Both marl-bands yielded poorly preserved remains, determined by Mr. H. A. Allen as *Estheria* cf. *minuta* (Alberti).

The ground is coloured on the old series 1 inch map (62 N.E.) as Upper Bunter (f^3); but the sandstones are coarser and duller in colour than the typical Upper Bunter of other Midland districts, and would more suitably be included in the outcrop of the Pebble Beds (f^2). The Triassic series dips at 3° to 5° toward E.N.E., in which direction the Pebble Bed subdivision appears to pass laterally into, and partly beneath, finer-grained and brighter-coloured sandstones that may be regarded as Upper Bunter. Above these follows the Lower Keuper Sandstone (f^5). There is thus no question as to the beds in the quarry being Bunter, and every ground for referring them to the Pebble Bed subdivision.

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4. The Relation of the Rhiwlas and Bala Limestones at Bala, N. Wales. By Dr. Gertrude L. Elles.

THE difficulties in the interpretation of the succession in the Bala district appear to be due largely to the impersistent nature of the limestones and their inconstancy as to horizon.

The succession is as follows:—

Hirnant Series	Hirnant Limestone (impersistent). Hirnant Flags and Mudstones. Rhiwlas Limestone (impersistent).
Bala Limestone Series	Bala Limestone (impersistent). Calcareous Ash. Mudstones. Coarse Ash. Mudstones and flags with thin impersistent Limestones. Ash. Sandy flags, with occasional impersistent Limestones. Ash. Sandy flags becoming shaly towards base.

The Rhiwlas Limestone is an impersistent limestone at the base of the Hirnant Series, and is found only in the northern part of the

area. The Bala Limestone is not developed as a calcareous bed in the northern part of the area, but is somewhat more persistent as a definite band in the southern and eastern portions of the district. The true relations of these horizons to each other is seen in the type section at Gelli Grin, where the Bala Limestone at its maximum thickness is overlain by light-coloured, pasty mudstones containing a typical Rhiwlas Limestone fauna. The fauna is not nearly so rich in individuals as that of the Rhiwlas Limestone itself, but all the more important genera and species seem to be represented. Confirmatory sections are also seen east of the fault near Gelli Grin Farm, and also on Bryn Cut.

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5. The Shelly and Graptolitic Faunas of the British Ordovician. By Dr. Gertrude L. Elles.

THERE are two main types of 'shelly' faunas of Ordovician age in the British Isles, and each of these can be further subdivided into a number of sub-faunas which can be correlated by reference to associated graptolite-bearing beds.

Ordovician Faunas.

Graptolitic	Shelly	
Graptolite Zones	A	B
Zone of Cephalog. acuminatus	Staurocephalus fauna	Staurocephalus fauna
Zone of Dicellog. anceps		Exotic fauna . 4
Zone of Dicellog. complanatus	Calymene planimarginata fauna with sub-faunas (*a*) Chasmops; (*b*) Asaphus Powisi	Exotic fauna . 3
Zone of Pleurog. linearis		
Zone of Dicranog. clingani		
Zone of Climacog. Wilsoni		
	—?—	
Zone of Climacog. peltifer	Ogygia Buchi fauna with Asaphus tyrannus sub-fauna	Exotic fauna . 2
Zone of Nemag. gracilis		
Zone of Glyptog. teretiusculus		Exotic fauna . 1
Zone of Didymog. Murchisoni	Placoparia fauna	
Zone of Didymog. bifidus		
Zone of Didymog. hirundo	Ogygia Selwyni fauna	
Zone of Didymog. extensus		
Zone of Dichograptus		

The main shelly types may be described as—

A. Asaphid-Trinucleid-Calymenid fauna.
B. Cheirurid-Lichad-Encrinurid fauna.

Evidence suggests that fauna B is an exotic fauna, possibly southern in origin, which migrated into the British area. Becoming early established in South Scotland, it soon spread west into Ireland, but did not dominate the whole British area till Ashgillian times.

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6. The Basal Carboniferous Beds at Lye, in South Staffordshire. By W. Wickham King, F.G.S., and W. J. Lewis, B.Sc.

In the Geol. Mag., Dec. V, Vol. IX, p. 437, 1912, we announced (*inter alia*) that *purple* beds of Lower Old Red age existed at Saltwells. Since then we have ascertained that 2 miles to the south, at Lusbridge Brook, Lye, below the Thick Coal, Carboniferous beds are exposed for a thickness of nearly 400 feet as against about 200 feet at Saltwells. These basal beds are difficult to interpret.

The succession below the Thick Coal in Lusbridge Brook is thus: (*a*) Various Clays and Coals, 280 feet; (*b*) Conglomerate, 27 feet; (*c*) Red Clays (Plants) and White and Yellow Clays, in which are embedded many pieces of quite unworn Cherts, and at base Limestone Grits and a Conglomerate, thickness 40 feet; (*d*) White, Red, and Yellow Clays. (*d*) is only exposed for about 30 feet. Total below Thick Coal, 377 feet. Mr. F. G. Meachem has kindly given to us data proving that the beds down to the base of (*b*) are the same thickness in the Freehold Pit, Lye, and that there, below (*b*), they pierced Red Marls for 150 feet.

The interesting zones are those in which the Limestone Grit and Cherts occur. Broken fossils occur in the Limestone Grit, which is made up largely of angular pieces of Limestone. In the Conglomerate (*b*) a pebble 18 inches in diameter of highly calcareous grit containing *Calamites varians* has been found, which is probably another type of this Limestone Grit. A precisely similar calcareous grit was found in situ at or below (*b*) in the Freehold Pit, and above (*c*) a nearly similar type occurs in the form of gigantic slabs 2½ feet thick in the Lye Cemetery.

The Cherts contain many casts of fossils, but they are so imperfect that we hesitate to name them. We found in the clays (*c*) a minute fragment of a Brachiopod with a straight hinge-line.

Pebbles of (*inter alia*) Limestone Grit and Cherts occur in the Conglomerates.

The Limestone Grits, Cherts, and Clays at Lye are such as might be laid down in the vicinity of a shore-line and there disintegrated in situ. In several respects they resemble the Rush Conglomerates of Lower Carboniferous age in Ireland. Compare Q.J.G.S., vol. lxii, p. 285.

In the Conglomerates there is distinct evidence of Inter-Carboniferous denudation which removed in places, as at Saltwells, the Coal-measure Ironstone (*Neuropteris*), Coal Seams, Grey Limestones, Limestone Grits, and Cherts.

In Q.J.G.S., vol. lv, p. 123, 1899, Mr. King showed that all the pebbles in the Permian Conglomerates of the Severn Basin are referable to a local source, except only those of Lower Carboniferous age. The last-mentioned pebbles contain *Syringopora* and *Caninia*.

Some of the pebbles that he regarded as of Lower Carboniferous age are identical lithologically with the Limestone Grits and Cherts now found at Lye.

In Permian times the Lower Carboniferous Rocks provided, from original and derivative local sources, much of the material in the Permian Calcareous Conglomerates.

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7. The Development of the Midland Coal-fields. By Fred. G. Meachem, M.E., F.G.S.

GREAT advances have been made in mining since the first meeting of this Association in Birmingham in the year 1839. Women were then employed in the mines, also children under 10 years of age, and all worked twelve hours or more in the pit. To-day women are not allowed to work in a mine, and no youth under 14 years, and the hours of labour are restricted by Act of Parliament to eight per day. Nearly all the mines worked in 1836 were shallow ones, and the output not more than 200 to 300 tons per week. The area of the coal-fields was about as shown below, as against the present known and concealed areas of coal.

Year.	South Staffs.	Leicester.	Warwick.	Salop.	Total square miles.
1836 . .	70	20	10	20	120
1913 . .	360	88	222	96	766

This last calculation includes the concealed coal-field between Chasetown, Aldridge, and West Bromwich on the west and the Warwickshire and Leicestershire Coal-fields on the east, and also the concealed coal-field between Cannock, Essington, and Stourbridge on the east of the Coalbrookdale and Forest of Wyre Coal-fields on the west.

The output since figures are available is as follows :—

Year.	South Staffs.	Leicester.	Warwick.	Salop.	Total in million tons.
1865 . .	10	$1\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{2}$	$13\frac{3}{4}$
1912 . .	$7\frac{1}{2}$	$2\frac{3}{4}$	$4\frac{1}{2}$	$\frac{3}{4}$	$15\frac{1}{2}$

This shows a great advance in industrial conditions and in Economic Geology, but the question of output does not show so great an increase; this I think is due, not to fear that the concealed coal-fields would not be profitable, but to the fact that some of the deeper mines have not proved remunerative. This is partly due to local conditions in the mines and also to the fact that the deeper coal costs more to get than the shallow coal, as regards actual working cost and the greatly increased capital needed, whilst the coal from both mines is sold in the same market, so that the shallow mine rules the selling price. As a few years pass by, and probably before the next meeting of this Association, the shallow mines will be exhausted, and the prices will be ruled by the deeper mines, with the usual economic results of increased prices in proportion to increased costs to get.

In the figures above, areas are included which were not thought of in 1836, but, as is fully shown by the report of the last Royal Coal Commission, 1905, coal will undoubtedly be found in the areas above named. The area between the South Staffordshire Coal-field and the Leicestershire and Warwickshire Coal-field will be found to be

one continuous coal-field, with its deepest part at Lichfield, Sutton Coldfield, and Coleshill, but the basin rising to the south as a whole, the thick coal of Sandwell and Hamstead will split up into two or three seams, and under these conditions will be worked Longwall, with better commercial results. The area between the Staffordshire Coal-field and Shropshire has been most vigorously investigated, and the proofs at Colwich, Huntingdon, Essington, Four Ashes, and Baggerridge show that this area is going to be rich in coals of good quality and laid down under conditions that will allow of remunerative working.

On the Shropshire side very little has been done to extend that coal-field to the west of either the Coalbrookdale or the Forest of Wyre Coal-fields; the edges of the Old Red Sandstone preclude any hope of extension, but in the Highley and Kinlet and Billingsley area it is most probable that future deeper sinkings will prove deeper coals than the two seams at present working, whilst the area to the east is full of promise. As soon as the Severn Valley Fault, which is some 300 to 400 yards downthrow east, is crossed, a new coal-field will be found, and I think the area between here and the old coal-field will be divided into two basins, with a Silurian anticline between them as proved by the Claverley boring.

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8. On the occurrence of a Wind-worn Rock-surface at Lilleshall Hill, Salop, and of Wind-worn Stones there and elsewhere. By Frank Raw, B.Sc., F.G.S.

LILLESHALL HILL, lying some 5½ miles north-east of Wellington, and extending north-east and south-west, is a 'hogsback' of Uriconian, and is largely bare rock. The exposed rock of its south-east side consists towards the north-east of very hard hälleflintas, interstratified with somewhat softer tuff, and to the south-west of this and opposite the Monument of still harder felsite conglomerate and grit.

Practically the whole of this rock-surface has been ground smooth and, where hardest, has been highly polished, the smooth surface being traceable everywhere except where it has obviously been removed by weathering or quarrying. The surfaces of projecting masses of the conglomerate are perfectly fresh, being ground smooth, deeply fluted, and polished as by wind-blown sand, the radiating flutings showing the paths of escape of the prevalent wind. To the north-east the rock-surfaces have been much more even, perhaps based on a previously glaciated surface, and the flutings are parallel and in that direction less and less highly inclined, till at the north-east end they lie at an inclination of 15° to 20° up to the north in north and south planes.

From the south-west end of the wind-worn surfaces already described similar polishing can be traced across the hill to the north-west on the steep rock-surfaces of quartz-veined hälleflintas which bound on the south-west the highest part of the hill.

South-west of this the crest of the hill is fairly flat and covered with grass. Here two reservoirs have been constructed for the

Lilleshall water supply, and several of the stones thrown out were found to be beautifully wind-worn and polished. Two trial excavations made near by yielded a considerable proportion of wind-worn stones embedded in fine soft red sand.

In one of the excavations carried to a depth of 29 inches there also occurred immediately beneath the turf a definite layer of white even-sized wind-worn sand, the grains measuring about $\frac{1}{30}$ inch in diameter, above the fine red sand with wind-worn stones.

The occurrence of wind-worn stones is also recorded from other localities in the Midlands, and specimens in illustration are exhibited.

9. Plant Petrifactions in Chert and their bearing on the Origin of Freshwater Cherts. By Marie C. Stopes, D.Sc., Ph.D.

THE author described, and illustrated with photos, petrifactions of plants in the freshwater cherts of Lulworth (Purbeck) and Asia Minor (Tertiary). The author drew special attention to the Asia Minor cherts, which are remarkably interesting and contain well-preserved plant debris. These were described by Mr. Haydon in his presidential address to the Liverpool Biological Society, but his work seems not to have reached most geologists and palæobotanists. The cherts contain beautifully preserved pollen grains, fungi, stem debris, etc.; and the existence of these delicate soft tissues so well preserved suggests that Sollas's view of flint formation can only be applied with caution to these freshwater cherts.

The author drew attention to the recent 'Sapropel' observed by Potonié, and the likeness it has to the debris in the Asia Minor chert; concluding that the chert may be taken as practically pure petrified 'Sapropel', a phenomenon which must interest those who are concerned with the methods of plant petrifactions.

REVIEWS.

I.—Geological Survey of a part of South Devon.

The Geology of the Country around Newton Abbot. By W. A. E. Ussher, F.G.S.; with contributions by Clement Reid, F.R.S., J. S. Flett, D.Sc., F.R.S., and D. A. MacAlister, A.R.S.M. 8vo; pp. vi, 148, with 3 plates and 14 text-illustrations. London: printed for H.M. Stationery Office, 1913. Price 3*s*.

THE country described in this memoir is a highly interesting and picturesque portion of South Devon, wherein are to be seen the fossiliferous Devonian limestones of Bradley Woods and elsewhere near Newton Abbot, and other Devonian strata with interbedded and intrusive igneous rocks; the Culm Measures with chert-beds and fossiliferous shales at Waddon Barton, near Chudleigh, and intercalated igneous rocks to the west, including portions of the Dartmoor granite at Lustleigh. Then the coast is dominated by fine cliffs of Red Rocks, ranging in upward succession from the Permian terra-cotta clay of Watcombe through the bold masses of conglomerate and breccia, sandstone and marl which extend to Teignmouth, Dawlish, and Exmouth. Beyond is the famous Bunter pebble-bed of Budleigh

Salterton, with overlying Bunter and Keuper Sandstones. Attractive also are the fossiliferous Upper Greensand outliers of the Haldon Hills, with their coverings of gravel grouped as Eocene; likewise the thick and varied deposits of the Bovey Basin, including the plant-bearing lignites and the pottery clays (now regarded as Upper Oligocene), and the overlying gravels and alluvial deposits, some undoubtedly Pleistocene, others of Holocene or Recent age. This great series of formations is well shown on the new colour-printed map, Sheet 339 (price 1*s.* 6*d.*), but the Pleistocene gravels have not been indicated in the Bovey Basin. The area in fact, as stated by the Director, Dr. Teall, in his preface, was to a large extent re-surveyed in 1874 and subsequent years on the old 1 inch map, particularly as regards the Permian and newer strata. This work was transferred to the new series map and published in hand-coloured form in 1899, considerable revisions having been made in the Palæozoic areas by Mr. Ussher. Still later revisions are included in the colour-printed edition of the map, and the mineral lodes have been inserted by Mr. D. A. MacAlister. The coloured section at the foot of the map is taken (perhaps wisely) to the north of the Bovey Basin, from the granite near Hennock, through Chudleigh, across Great and Little Haldon, and over the Red Rocks to Exmouth and East Budleigh.

An area containing so much of interest has naturally attracted many geologists, and among the early workers Godwin-Austen (then Austen) was conspicuous. Residing for a few years (from about 1831) at Ogwell House, near Newton Abbot, he prepared a geological map of the country, published in an elaborate and philosophical memoir in 1842 by the Geological Society; but the results of his field-work were given by Austen to De la Beche, who utilized them in the original Geological Survey map, Sheet 22, which was published in 1834. Of other workers H. B. Holl, and subsequently Arthur Champernowne, devoted much time to geological mapping, while J. E. Lee, G. F. Whidborne, Dr. Henry Woodward, Dr. G. J. Hinde, and Mr. Howard Fox added much to the knowledge of the palæontology of the older formations. It is remarkable, however, considering the careful account given of the literature, and the list of published papers, that no mention is made of the "Notes on Parts of South Devon and Cornwall" by J. B. Jukes (Roy. Geol. Soc. Ireland, 1868). In that paper Jukes records a meeting with Dr. Holl in a quarry near Newton Abbot, when he "laughingly remarked to him that 'one might toss up whether the beds were vertical or horizontal', for there were planes of division in both directions, either of which might be planes of stratification and the other joints".

To Mr. Ussher, who commenced work in the area in 1874, we are indebted for the elucidation of the main structure of the area, as regards not only the Devonian and Carboniferous, but also the Permian and Trias. His main conclusions on the older rocks were given in a paper published by the Geological Society in 1890. He now amplifies the information and gives details of the Devonian and Carboniferous subdivisions. It is observed that "as a whole the impersistence of the Devonian limestone is clearly proved, but direct

evidence is wanting as to the original extension of the limestone in individual districts". While mostly of Middle Devonian age, certain parts of the limestone "may represent the Cuboides-stage of the Continental Upper Devonian". The higher portion of the Upper Devonian is represented by the *Goniatites-intumescens*-stage at Lower Dunscombe. The names of the Devonian fossils collected during the course of the survey have been revised by Dr. Ivor Thomas.

It is noted that in the Lower Culm Measures the chert-beds seem to be developed on different horizons, "immediately beneath the *Posidonomya*-beds and perhaps to some extent intercalated with them," and at lower positions down to the local base of the series.

The interbedded and intrusive igneous rocks of the Devonian and Carboniferous are described by Dr. Flett, who calls attention to the occurrence of spilites showing excellent 'pillow-structure' near Bickington. Schalsteins and quartz-keratophyres are likewise described. The intrusive rocks include diabases, proterobases, picrite, and portions of the Dartmoor granite, with felsites. Accounts are given of the contact alteration produced by the diabase sills, and of the metamorphic aureole bordering the granite.

The Permian rocks, including the basalt of Dunchideock, and the Trias are described by Mr. Ussher, and the Upper Cretaceous by Mr. Reid, who has naturally relied on Mr. Jukes-Browne for most of the particulars.[1] In transcribing "his account with a few modifications", it would have been well to have used inverted commas for the quotations, and to have inserted the modifications within brackets. The Eocene and Oligocene deposits are described by Mr. Reid, who gives his reasons for separating the Eocene, and presumably Bagshot, gravels of Haldon from the similar gravels at a lower level in the Bovey Basin. Much has yet to be done in following the connecting links between the Bagshot gravels of Black Down near Portesham in Dorset and the South Devon deposits. Details are given of the Bovey Beds, with list of plants, the majority of which have been determined by Mr. and Mrs. Reid to be "identical with species found in the well-known brown-coal deposits of Germany. These are now generally accepted as the highest Oligocene strata, though certain authorities class the Aquitanian stage as lowest Miocene".

The remaining portions of the memoir contain accounts of caverns and fissures, river gravels and head, recent changes, water supply, metalliferous deposits, building-stones, clays, lignites, etc. There is one plate of photomicrographs of igneous rocks, and another showing much-weathered Triassic sandstone resting on the Budleigh Salterton Pebble-bed.

II.—Geology and Forestry.

DURING the past few years the subject of afforestation has attracted more and more attention, and considerable areas of gathering ground connected with waterworks, as well as some tracts rendered barren and unsightly by tips from mines and quarries or by

[1] Memoir on Cretaceous Rocks of Britain, vol. i, 1900.

furnace refuse, have been successfully planted. Larger schemes for woodlands, more directly intended for economic purposes, are under consideration, and as their success depends fundamentally on geological considerations, on soil and substrata, on ground-water and drainage, which affect available plant-food, it is well that geologists should give some attention to the subject. We are glad, therefore, to see an article on "The Use of Geology to the Forester" (Trans. Foresters and Gardeners Society of Argyll for 1912, 1913), by Dr. C. B. Crampton, of the Geological Survey of Scotland. He emphasizes the need of giving attention to the horizontal and vertical distribution of the various rocks and soils, and their relations to the physical features. The formation of soils and subsoils on different types of rock is briefly explained; descriptions are given of screes, landslips, rain-wash, pan, etc.; and there are notes of trees and shrubs suitable for certain situations, having regard to geological, physiographical, and climatic conditions.

Special reference is made to the Scottish Highlands and to the effects of glaciation, whereby old soils were removed and large tracts rendered infertile, the results being summed up as "a baring of glaciated unweathered rock surfaces at all levels—a smothering of wide areas by sterilised and more or less impermeable boulder clay, and the piling up of loose glacial debris and leached sands and gravels". Extensive areas of this transported material, however, are under cultivation by the agriculturist, but as a rule they would not be suitable for plantations without the benefit of tillage.

While some of the Geological Survey maps, especially those of the old hand-coloured editions, "form but a framework so far as the needs of the forester are concerned, since they give little indication of the presence or nature of subsoils and soils," it should have been added by the author that for South Wales and for many Midland and Southern counties of England, there are a number of published and many more MS., six-inch geological maps (copies of which can be purchased) that show in detail the superficial deposits. Moreover, even the published one-inch drift maps have been found by Mr. A. D. Hall and Dr. E. J. Russell to be of essential service in their important soil researches; and such maps are now issued by the Geological Survey of Scotland.[1]

III.—Annual Report of the British Museum for 1912. Pp. 212. H.M. Stationery Office, 1913. Price 10½*d.* net.

THE annual return, which made its customarily tardy appearance at the end of the summer, some seven months after the close of the year to which it refers, contains beneath a forbiddingly statistical air a great deal of interest, and is eloquent testimony to the important work being done by the expert staff at both branches of this great institution. Considerably more than half the number of pages are taken up with the Natural History Museum, and it is with these that we are mainly concerned here. We are glad to note a recovery from the great drop in the number of visitors reported in the previous year, though the numbers still remain some way below

[1] See Geol. Mag., 1911, p. 377.

those chronicled for 1910, and it is encouraging to notice a steady increase in the number of visits paid for purposes of study. The appointment of an official Guide to take members of the public round various parts of the museum daily, free of charge, has been much appreciated, and evidently meets a widely felt want. It is to be hoped, too, that the example of the parent institution in putting on sale picture postcards or other reproductions of objects of interest in the museum will be followed at South Kensington; such means of drawing attention to the museum and therefore of increasing its usefulness are not to be disdained. The rapid growth of the entomological collections and the importance of insects in relation to the spread of disease in man and in animals have led to the separation of the Entomological Section from the Zoological Department, and Mr. C. J. Gahan, formerly senior assistant, has been made the first Keeper of Entomology. So great is the congestion in the collections on this side of the museum that an extension of the building westward is under consideration. Dr. Jehu gave his fourth course of Swiney lectures in December and January, his subject being "The Record of Life as revealed in the Rocks". His appointment has been extended for another year, and he proposes to give a course of lectures in December on "The Natural History of Minerals and Rocks".

IV.—United States Geological Survey.—Water-supply Paper No. 292 (1913) continues the account of the surface water-supply, as part xii, North Pacific Coast. In No. 314 (1913) the "Surface Water-Supply of Seward Peninsula, Alaska" is described by Messrs. F. F. Henshaw and G. L. Parker, and included in the report are a sketch of the geography and geology by Mr. Philip S. Smith, and a description of the methods of placer mining by Mr. Alfred H. Brooks. The subjects are well illustrated by a geological map; a topographical map, on which are marked the gauging and rainfall stations and the placer deposits; and numerous pictorial views of flumes and other artificial water channels, and of mining operations and sluicing. In Water-supply Paper No. 317 (1913) Mr. C. H. Gordon reports on the 'Geology and Underground Waters of the Wichita Region, north-central Texas".

MISCELLANEOUS.

At a meeting of Council in September, 1913, Dr. F. H. Hatch, M. Inst. C.E., F.G.S., etc., was duly elected President of the Institution of Mining and Metallurgy for 1914.

Dr. T. F. Sibly, F.G.S., Lecturer in Geology in King's College, London, has been appointed Professor of Geology in University College, Cardiff.

Mr. T. Sheppard, F.G.S., Curator of the Municipal Museums, Hull, has been elected President of the Yorkshire Naturalists' Union for the ensuing year. He had already filled the office of Honorary Secretary to that body for several years past with great success.